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SHIPYARD WELDING WORKMANSHIP

Recommendations for Welders and Welding Leadermen

PREPARED BY
U. S. COAST GUARD
BUREAU OF SHIPS, U. S. NAVY
U. S. MARITIME COMMISSION
AMERICAN BUREAU OF SHIPPING

Shipyard Welding Workmanship

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NAVCG 137

Ship Construction Manual No. 1

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FOREWORD

During the first years of this war we had to build many ships and build them quickly. We had to take the risks that go hand in hand with an extremely high rate of production. Our military forces and our war materials had to be carried across the oceans to our allies and to our own front lines throughout the world. Merchant ships and Naval auxiliary vessels had to be built, launched and delivered within weeks instead of many months. The Army and Navy demanded ships "now". They got them.

Throughout that period the shipyard welding organizations have done a tremendous job. Without this welding, these ships could not have been built and delivered so quickly. Welded ships have proved their efficiency, reliability and seaworthiness under all types of service and under all weather and loading conditions. In relation to the ships built, the percentage of complete failures is small. Although there have been structural failures in these vessels, there have been structural failures in riveted ships as well.

Because of limited service at sea, prior to 1943, there was little evidence available with which to determine the major causes of ship failures. Since that time, however, the Navy, the Coast Guard, the American Bureau of Shipping, the Maritime Commission, and the National Bureau of Standards have photographed and analyzed scientifically many structural failures of ships under construction and in service. From this analysis have come lessons for us to apply in shipyard welding. Some of the data used in this research—the photographs, the descriptions of the failures, and the studies of causes and cures—has been incorporated into this booklet.

Shipyard employees rarely see the ship they have worked on after it has left the shipyard. Consequently, they have no way of learning how their ships are standing up under service. There have been numerous ship failures, some involving only one or two plates, others in which ships have broken in half. A though defective welding may not have been the sole cause of failure, defective welds have been considered major contributing factors in many cases.

After seeing the evidence in this booklet, the craftsmen and their supervisors, as well as the shipyard management, will want to increase their efforts to prevent the making of defective welds. We therefore urge each shipyard to use this material promptly and to the fullest extent in the immediate training of all foremen, leadmen and craftsmen concerned with welding.

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INTRODUCTION

It is not generally realized by workmen and supervisors of the various crafts connected with the welding of ships that a small fault in a weld, in a critical location in a ship, can result in serious fractures endangering the vessel. It is the purpose of this booklet to demonstrate this fact with photographs and descriptions of such structural failures.

The production of poor welding is seldom deliberate. Most welders, prompted by pride of workmanship, sense of fair play, and loyalty to country, have a natural desire to do good work. Men are proud to have helped in creating a ship. Defective welding is generally due to a lack of comprehension on the part of management, supervisors, and craftsmen of the possible serious consequences of minor deviations from good welding and shipfitting practices.

The loss to the war effort as a result of ship casualties is in many cases beyond calculation. In some cases, ships have had to leave a convoy for repairs and return to port without protective escort. Their valuable cargo did not reach the war front when needed. Such delays have contributed to the loss of many lives among Allied fighting men. The extra man-hours consumed in repair work, the costly materials used in repairs, and the taxing of overloaded dry dock facilities and other repair equipment—all these represent a serious set-back to the war effort. The removal from operation of vitally needed cargo or troop carriers results in serious dislocation of schedules.

The test of workmanship is service at sea. Two years ago there was insufficient information available concerning the extent to which defective welding might be responsible for ship failure. Today, as the result of investigations, there is evidence to prove that in many cases poor workmanship has been an important contributing factor in the fractures which have occurred on welded vessels.

The aim of this booklet is to provide illustrated material which can be used to demonstrate to shipyard personnel the need of high quality workmanship and to stimulate the desire to make sound welds at all times. It is intended to supplement but not supersede other publications put out by Government agencies and the American Bureau of Shipping. This booklet is of utmost importance to the welder because in the postwar era his own security and that of his family will depend increasingly upon his workmanship as a skilled craftsman.

A defect in a weld is a notch and, if located in a strength member, may cause the vessel to fracture. To understand this fact more clearly, let us use a few common comparisons. Everyone who has tried to tear a piece of cellophane or scotch tape knows how difficult it is; yet a small rip in the piece allows it to be torn quite easily. When a glazier wishes to break a piece of glass, he makes a notch or scratches a line in it and the glass breaks at that notch or line.

These are but two examples of the evidence which we see in our everyday lives that materials break readily at the place where there is a notch or rip. In the same way a notch in a weld can contribute to the start of a fracture which may penetrate the steel plates of a vessel.

In cases of ship failures where it has been possible to examine the fracture, investigators have been able to trace it back to its source by means of the herringbone pattern or chevrons which form on the edge of a fractured plate. The apexes of the herringbone always point toward the origin of the fracture. The failures which have been chosen as examples in this booklet are ones in which the herringbone pattern indicated the source of fracture to be in a faulty weld.

In determining the cause of a ship failure, every possibility is considered during the investigation, such as torpedoing, natural internal explosion, sabotage, mine, submerged obstruction, design, materials, and fabrication defects. Of these causes, it is the latter with which this booklet is concerned. No attempt is made in this booklet to analyze the other contributory factors in the ship failures presented as examples.

The choice of casualties used as illustrations was based solely upon the availability of complete sets of photographs and on no other factor. Many ships which might have been better examples could not be used because the photographic record was incomplete.

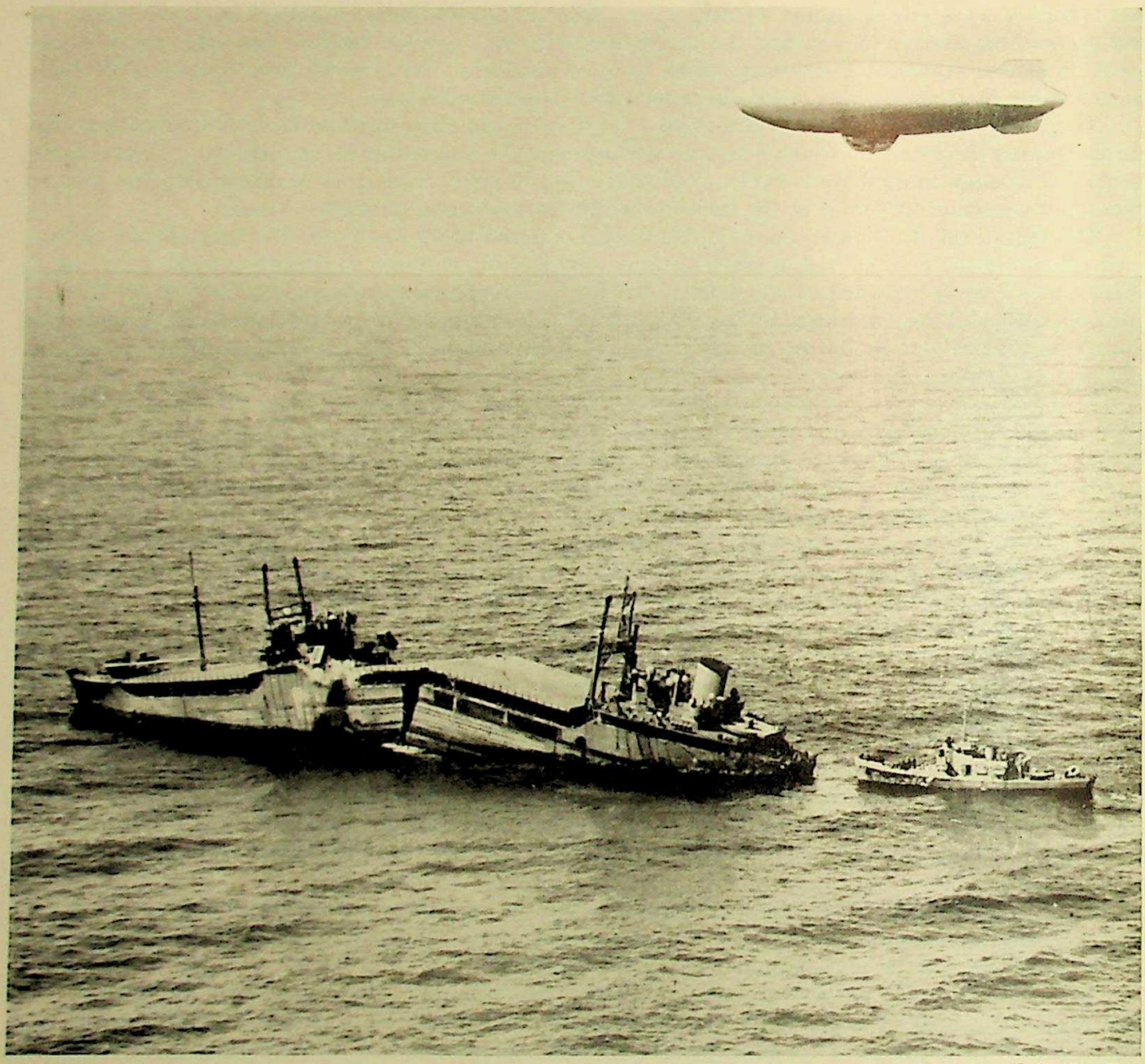
It is believed that nothing convinces a person so absolutely as to see a thing for himself. For that reason the booklet is profusely illustrated with photographs, all of which have been taken from official files. In many cases the photographs are self-explanatory and, by examining them, the reader may be able to note the type of faulty workmanship which caused the weld defect.

T2 TYPE TANKER

EXAMPLE 1

While en route in ballast from New York to Curaçao, this tanker broke suddenly in two. The vessel was about 25 miles outside Ambrose Channel; the weather and sea were moderate. There was no warning other than a sudden noise variously described by some of the crew as a sharp crack, and by others as a dull thud. The ship split in two between the Nos. 5 and 6 tanks, and jack-knifed (figs. 1 and 2). The fracture angled gradually aft from the centerline and then vertically down the ship's sides. The bottom plating was completely severed when the bow section veered to port (fig. 3).

An SOS was sent out, as it was suspected that the vessel had been torpedoed or had struck a mine. All hands abandoned ship immediately on the order of the captain; all four lifeboats and two life rafts were launched. Shortly afterward the entire crew was picked up by a Coast Guard cutter



U. S. Navy Photo

FIGURE 1—Aerial view of failure of T2 Tanker taken from one of two blimps convoying vessel.

and brought to port. The bow and stern halves remained afloat and were towed to a ship repair yard (figs. 4 and 5).

At the time of the failure, the tanker was being convoyed by two Navy lighter-than-air craft. The personnel aboard the blimps observed the breaking-up of the ship and obtained photographs at the various stages. For this reason the pictorial record of this failure is one of the finest records of a ship failure available.

By noting the apexes of the herringbone patterns, men who inspected the ship after failure were able to trace the fracture to three separate origins (figs. 6 and 7). As indicated in the photographs, these were located very close together in a butt weld in the main deck near the centerline strake at a point about 3 feet aft of frame 56 (fig. 8). Upon examination each of these three sources was found to contain large cracks, oxide scale, slag and considerable porosity, all of which originated during welding (figs. 9, 10, 11, and 12).

There is no doubt in this case that the imperfect weld was a major contributing factor in the failure of the ship. It presented an ideal source for the initiation of a fracture which, once started, progressed unchecked across the deck and down each side, resulting in the complete failure of the vessel.

The two sections of the tanker were welded together on drydock, where the ship remained out of service for 63 days. The cost of the repairs on this vessel was $426,626.

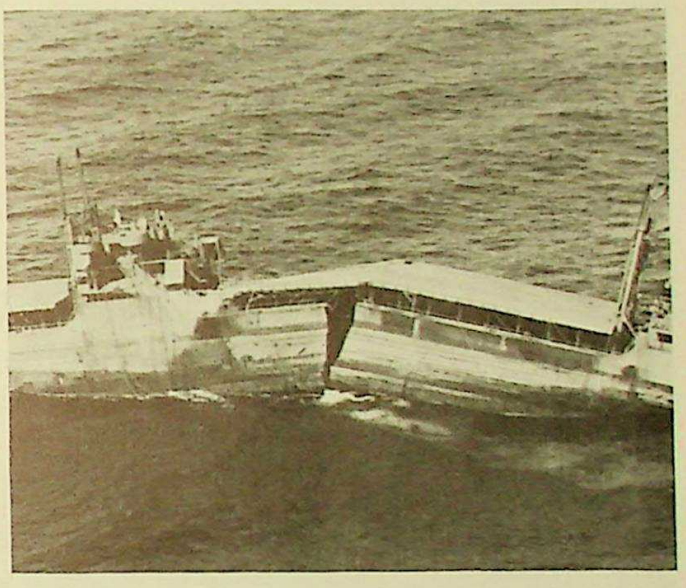


FIGURE 2—Aerial view of T2 Tanker breaking in two. Note that lifeboats have been launched and ship has been abandoned.

U. S. Navy Photo

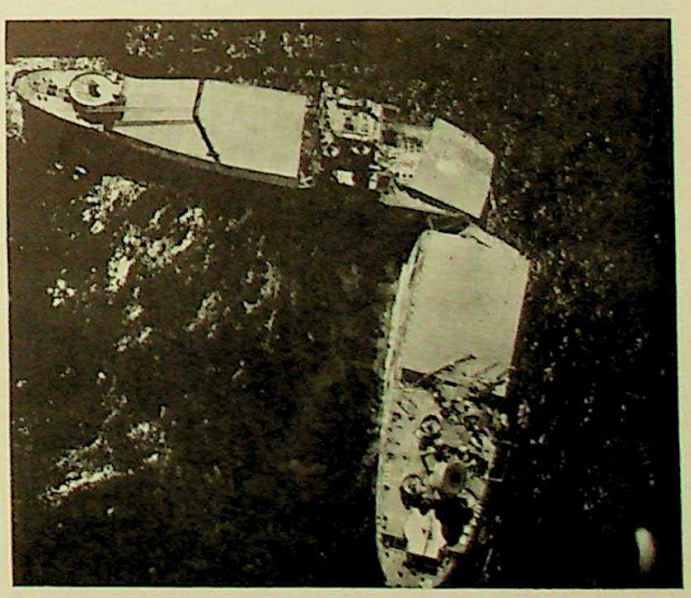
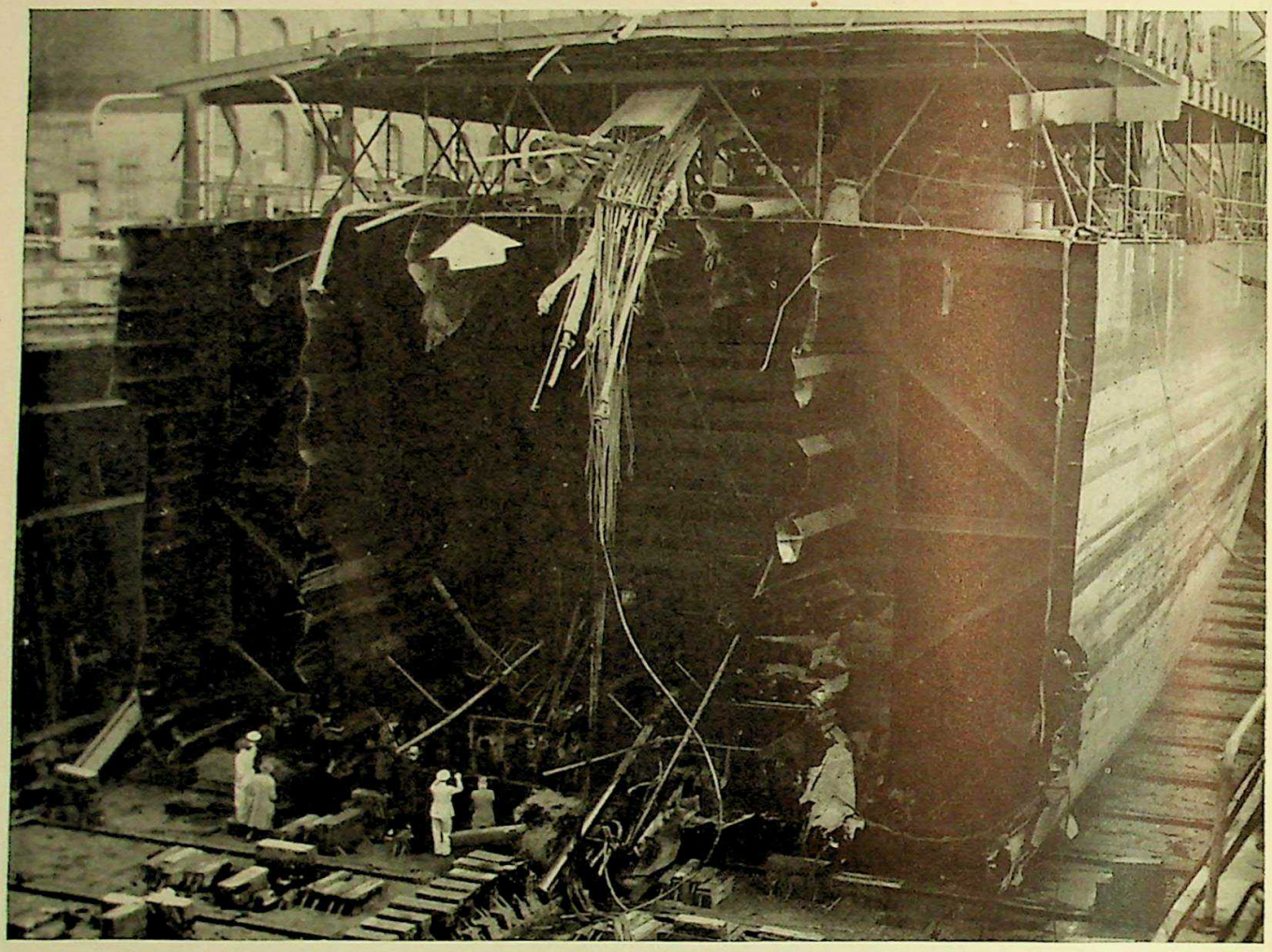


FIGURE 3—Forward section of T2 Tanker veers to port, and vessel splits completely in two. Overhanging portion is section of light wood runway used for transporting airplanes as cargo.

U. S. Navy Photo

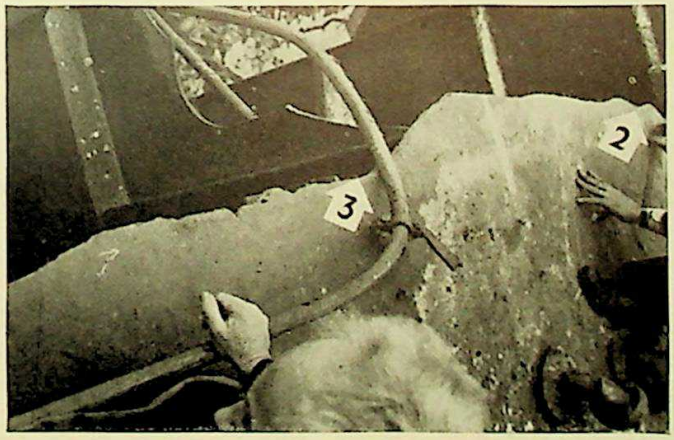


U. S. Coast Guard Photo

FIGURE 4—Aft portion. Arrow points to origin of fracture.

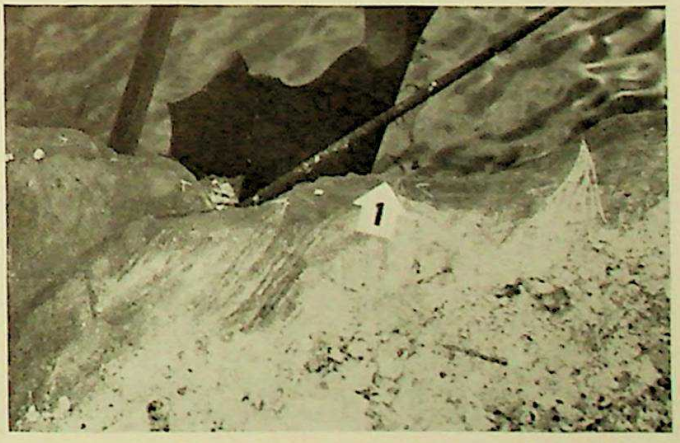
U. S. Coast Guard Photo

FIGURE 5—Forward portion, starboard side looking to port. Fracture started on main deck near centerline strake between Frames 55 and 56.



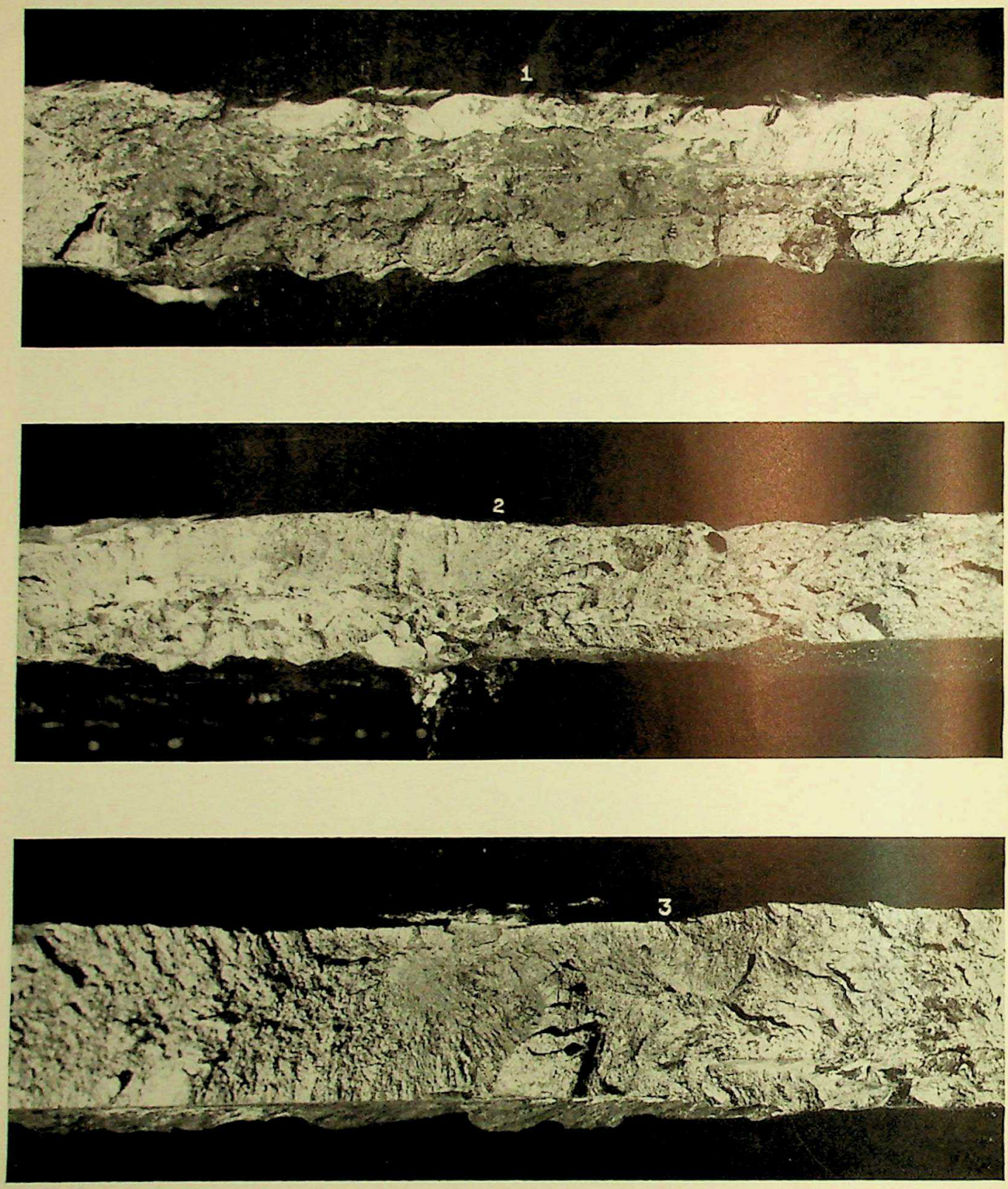
U. S. Navy Photo

FIGURE 6—View looking down on location in main deck where vessel broke in two. Arrows mark fracture sources 2 and 3 in butt weld.



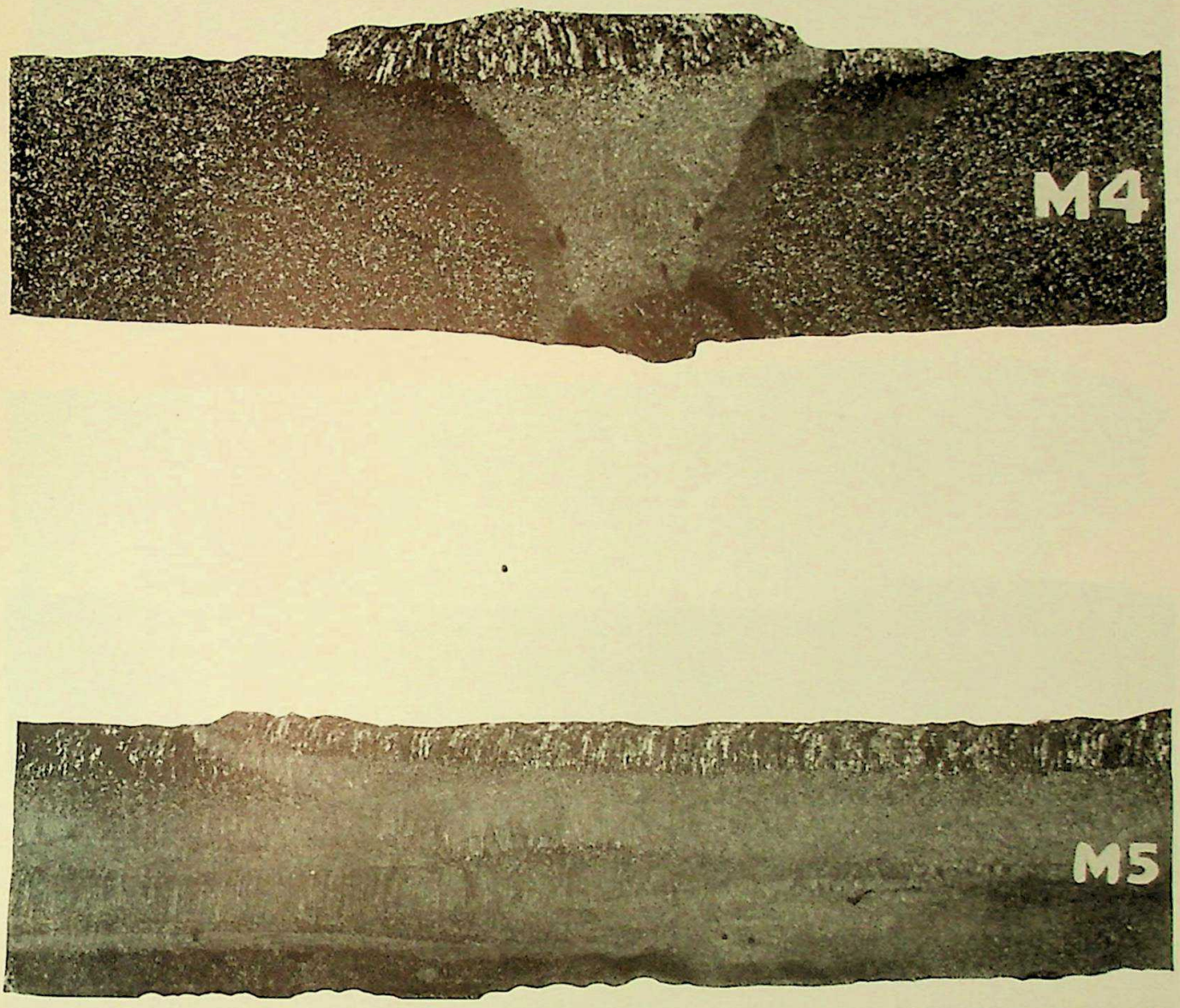
U. S. Navy Photo

FIGURE 7—Vertical view of fractured section of vessel looking from main deck toward the water. Arrow marks fracture source 1 in butt weld.



National Bureau of Standards Photo

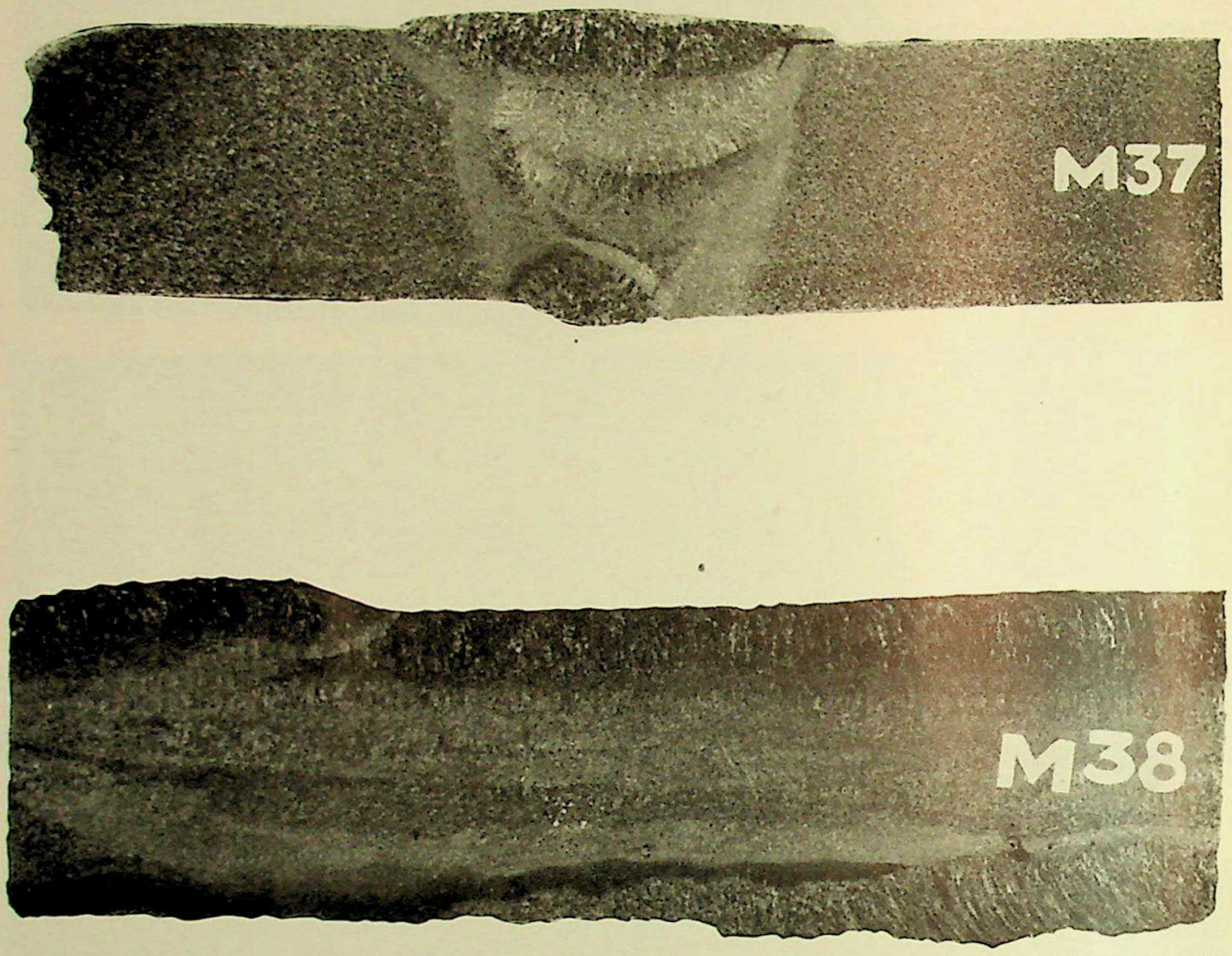
FIGURE 8—Fracture sources 1, 2 and 3. X2 approximately.



National Bureau of Standards Photo

FIGURE 9—Macrospecimens taken from same weld at a point about 15″ from source 3.

Note porosity, slag inclusions, incomplete penetration in Specimen M–4. In Specimen M–5, note small longitudinal crack and considerable amounts of slag in overhead pass at bottom of joint.

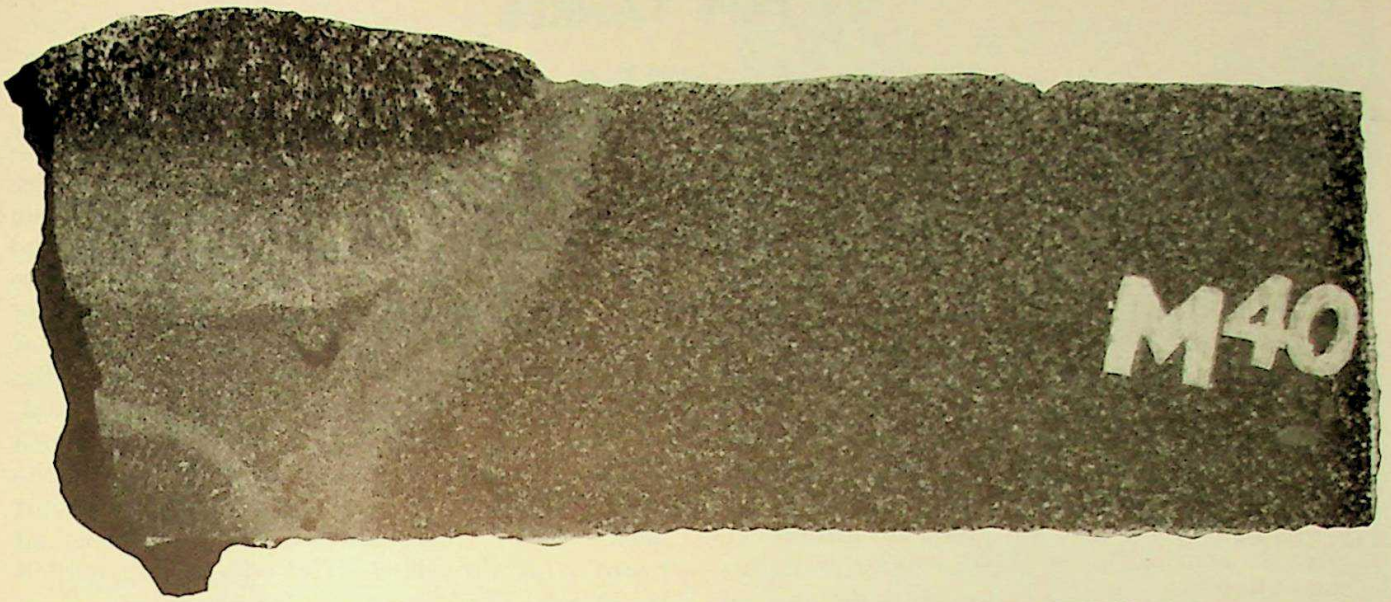


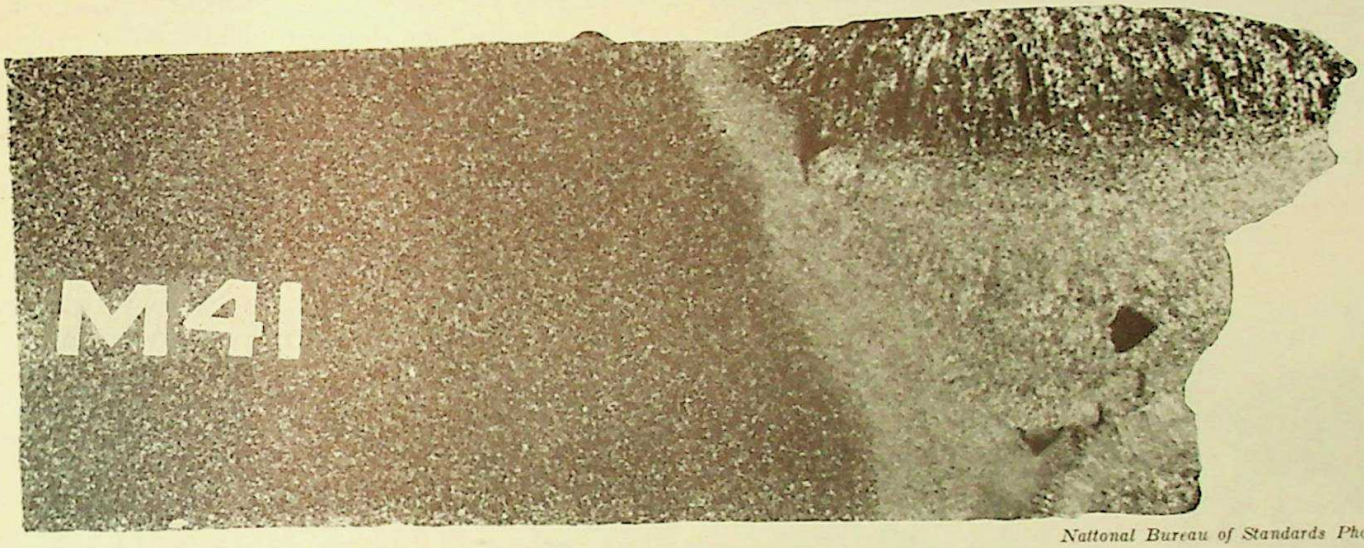
National Bureau of Standards Photo

FIGURE 10—Macrospecimens taken from the butt joint about 10″ from fracture source 2.

In Specimen M–37, note slag-filled crack at top of weld extending downward from the heavily peened area along the bead zone. The top of the bead had been peened over, covering the crack.

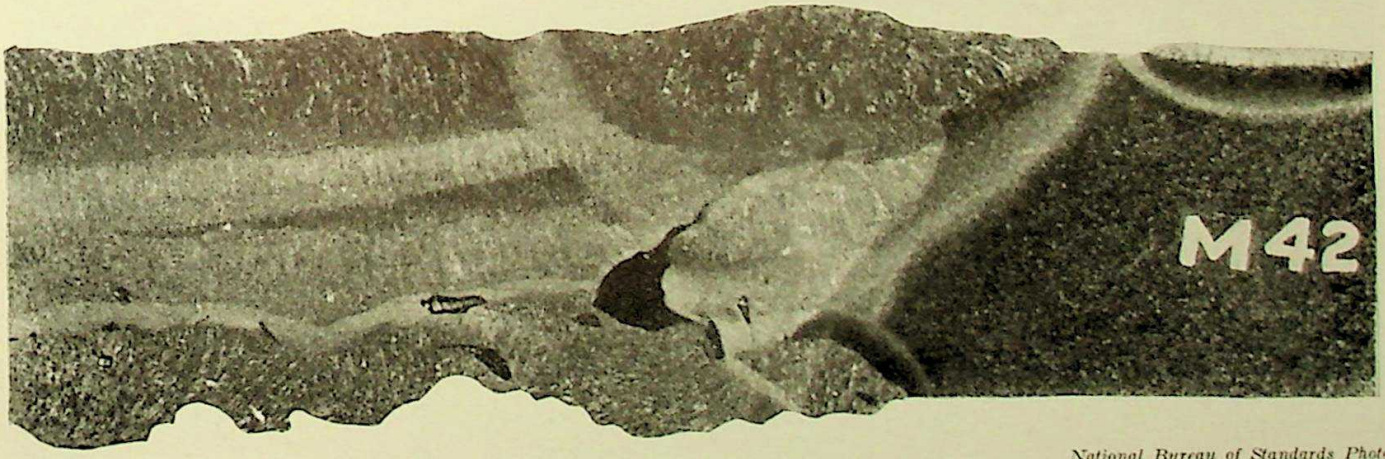
In Specimen M–38, there is a crack on the right side extending upward from the overhead pass at the bottom of the joint. Considerable porosity and slag inclusions are also present.





National Bureau of Standards Photo

FIGURE 11—Macrospecimen M–40, from fracture source 2, contains magnetic slag or scale. Macrospecimen M–41, from fracture source 1, shows slag or oxide scale inclusions.



National Bureau of Standards Photo

FIGURE 12—Macrospecimen taken at junction of defective butt weld and seam weld. The walls of the black hole were found to contain slag deposits. Other cracks in the specimen were filled with slag and scale.

T2 TYPE TANKER

EXAMPLE 2

Without any warning and with a report which was heard for at least a mile, this tank vessel cracked suddenly at No. 5 cargo tank and broke virtually in two. The failure occurred shortly after the completion of trial runs while the vessel was moored at her outfitting dock. The fracture extended almost instantaneously across the deck and down the sides just aft of the deck house to the turn of the bilge, port and starboard (fig. 13).

The bow and stern settled into the silt of the river bottom and the center portion rose about 2 feet above the water. The deck, side shell, longitudinal bulkheads and bottom girders all fractured, causing a complete structural failure of the ship (fig. 14). Except for a distance of about 10 feet in from the bilge on each side, the bottom plates remained intact, preventing the ship from severing completely (fig. 15).

At the time of the failure, about 10:30 at night, there were approximately 25 of the crew and 9 of the U. S. Navy Armed Guard on board. The Third Assistant Engineer, one fireman and one oiler were on watch in the engine department; in the deck department, the Third Mate was left in charge of the night watch aboard. Also on watch was an armed guard, consisting of three men under the charge of an Ensign. In an investigation of the failure of the vessel, this officer described the accident as "a perfect crack. The bow settled. There was a terrific shake . . . a jar." When he ran up to the captain's deck and out on the bridge, he saw that part of the ship was not there. He then ran down to the lower deck and heard everyone yelling, "Get off the ship, get off the ship!" The steam rising from the engine room gave the impression that there had been an explosion or that a fire was in progress. The suddenness with which the vessel jack-knifed caused all the officers and crew aboard to jump onto the dock as hastily as possible. In doing so, the Third Mate

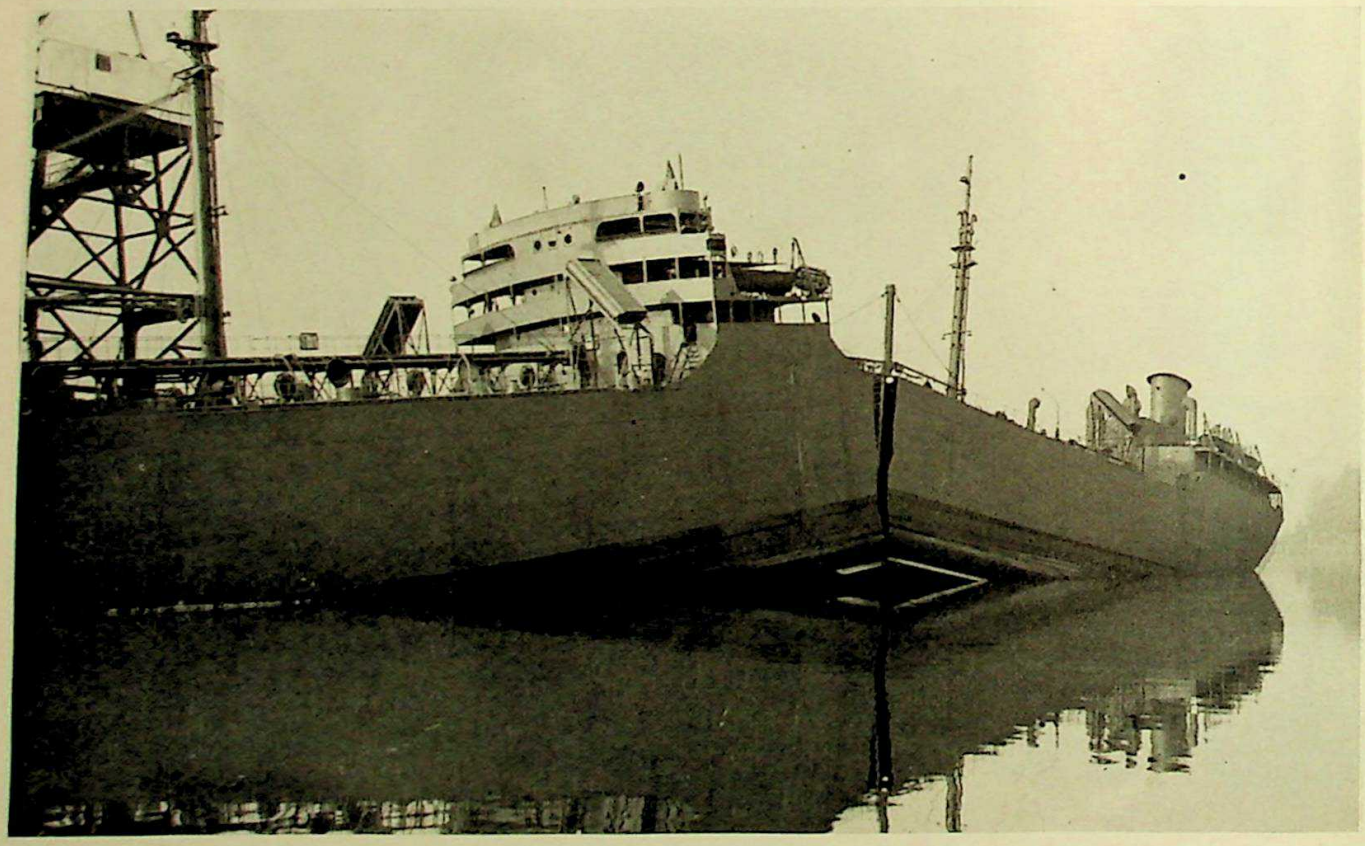


FIGURE 13—View of T2 Tanker after splitting in two at her outfitting dock.

broke two toes. This was the only injury which resulted from the accident.

Examination of the herringbone pattern on the fractured plates revealed the source of fracture to be at the joint of the starboard shear strake and the bridge superstructure fashion plate (fig. 16). From the point of initial fracture, the fracture extended down the starboard side and also across the deck and down the portside to the bottom of the shell plating.

The weld between the fashion plate and the sheer strake was decidedly defective in that it did not penetrate into the sheer strake for about 1 inch and it contained large slag inclusions (fig. 17 and 18). Evidence indicates that speed of travel was too high and the current too low to produce adequate penetration and to permit the slag to float out of the weld. Cracks emanated from several slag inclusions and these tended to decrease the strength of the joint. This weld, which was one of the major contributing factors in the failure of the vessel, was apparently made by a careless or inexperienced operator.

As the result of this fracture involving poor workmanship, the vessel remained in dry dock for 32 days. The cost of repairs was $265,450.

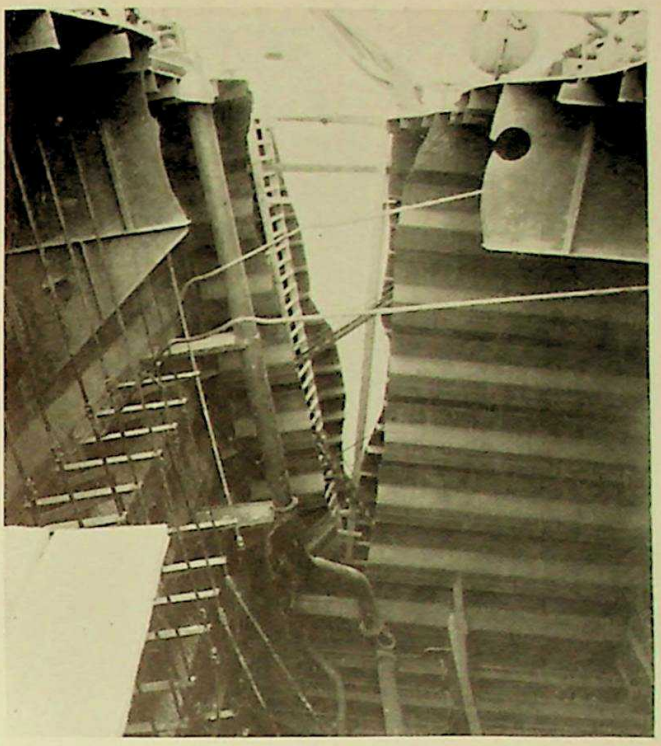


FIGURE 15—View inside crack showing complete fracture of longitudinal bulkheads.

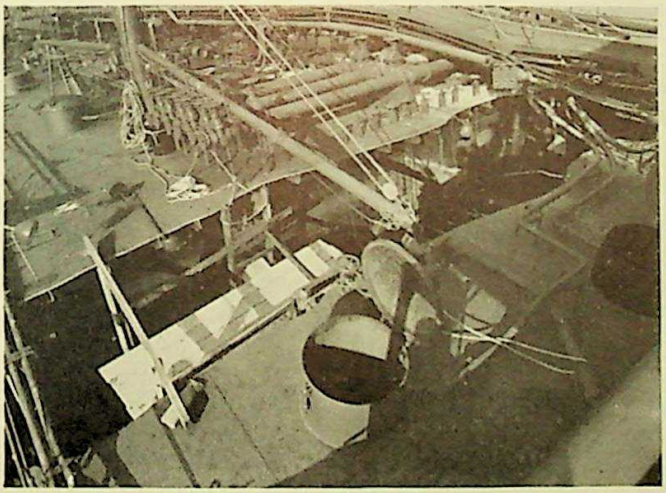
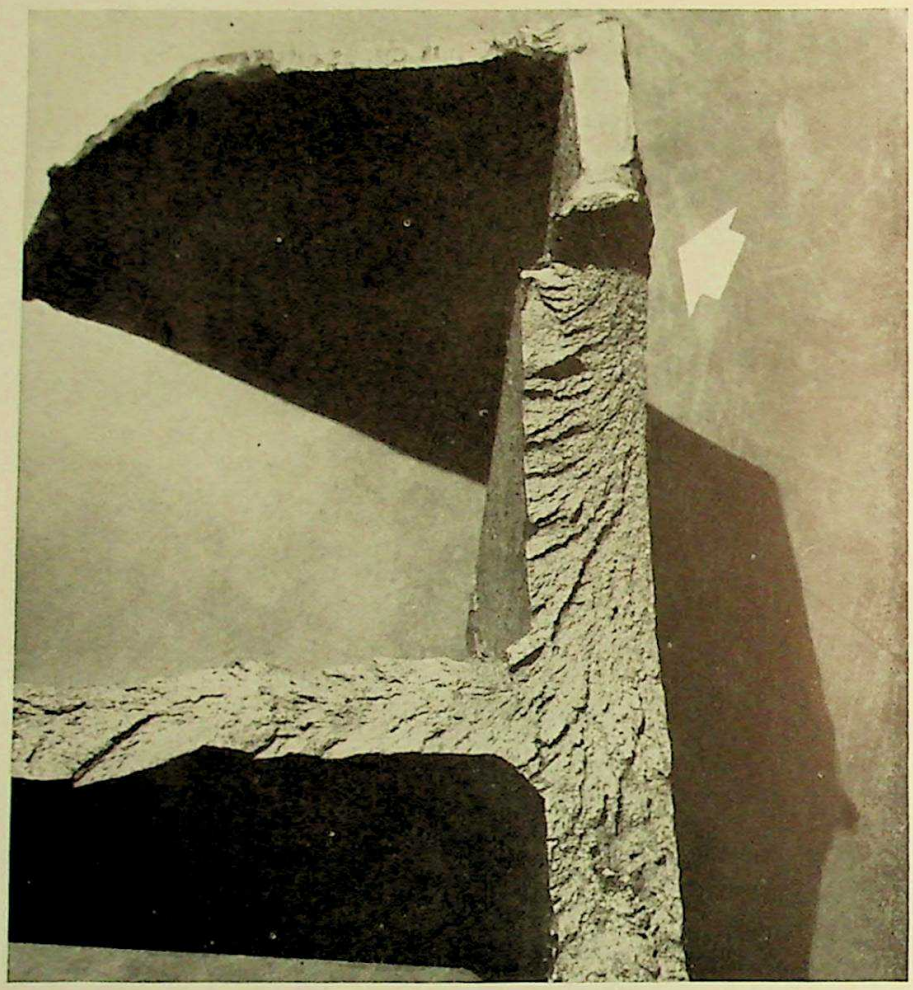


FIGURE 14—View looking down at inside of crack across deck.



National Bureau of Standards Photo

FIGURE 16—Section of the starboard gunwale and deck stringer. Arrow points to origin of fracture in weld at junction of deck house fashion plate and sheer strake.

FIGURE 17—A portion of the starboard sheer strake (lower right) and the weld metal (center), taken from junction of fashion plate and sheer strake. Note large area of non-fusion in weld metal.

Bureau of Standards Photo

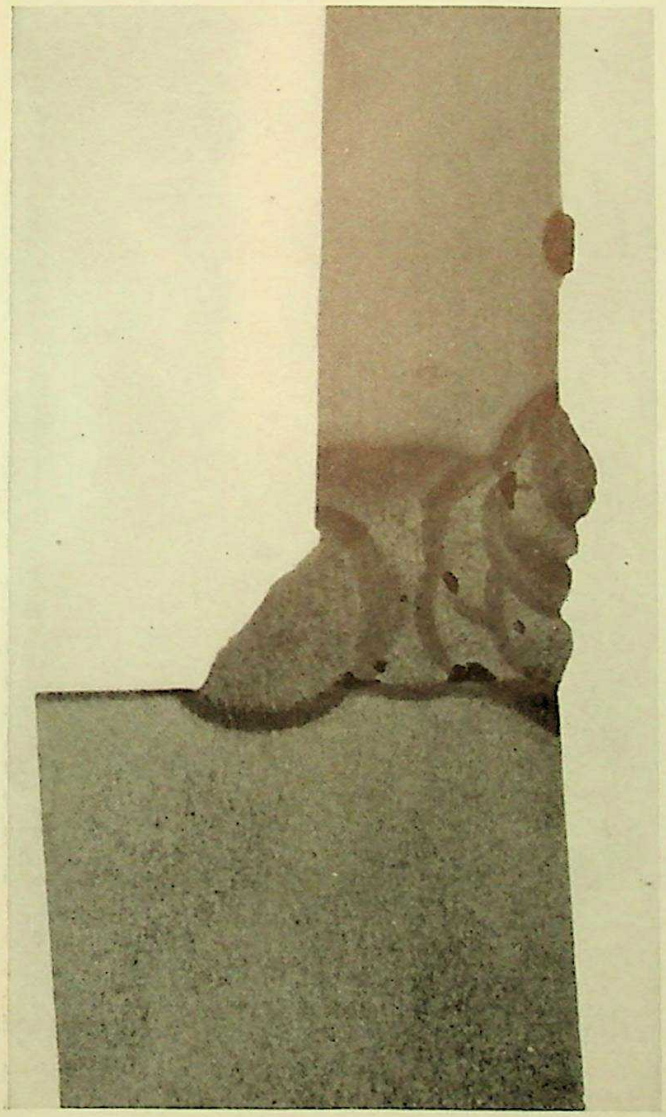


FIGURE 18—Weld joint between fashion plate (top) and sheer strake (bottom). Note deposit of electrode on fashion plate caused by striking the arc away from weld and dragging the electrode across plate to joint.

National Bureau of Standards Photo

ORE CARRIER, L6 TYPE

This ore carrier, while lying afloat at the builder's berth, and still under construction, sustained a fracture in way of No. 9 hatch at frame No. 100 (fig. 19). The cracks started in the butt welds in the hatch side longitudinal girders, port and starboard, and ran across the deck and down each side of the vessel to the top row of rivets in the lower seam of the sheer strake. The cracks extended through the hatch coamings above the deck and also down the sides of the hopper about 10 feet from the deck (figs. 20, 21, 22, 23).

Examination of the welds in the upper flange of the longitudinal hatch side girders (figs. 24 and 25) revealed imperfect fusion and it was discovered that these faulty welds were definitely contributory factors in the structural failure of this vessel.

The repairs to the vessel cost $40,000 and required 23 days.

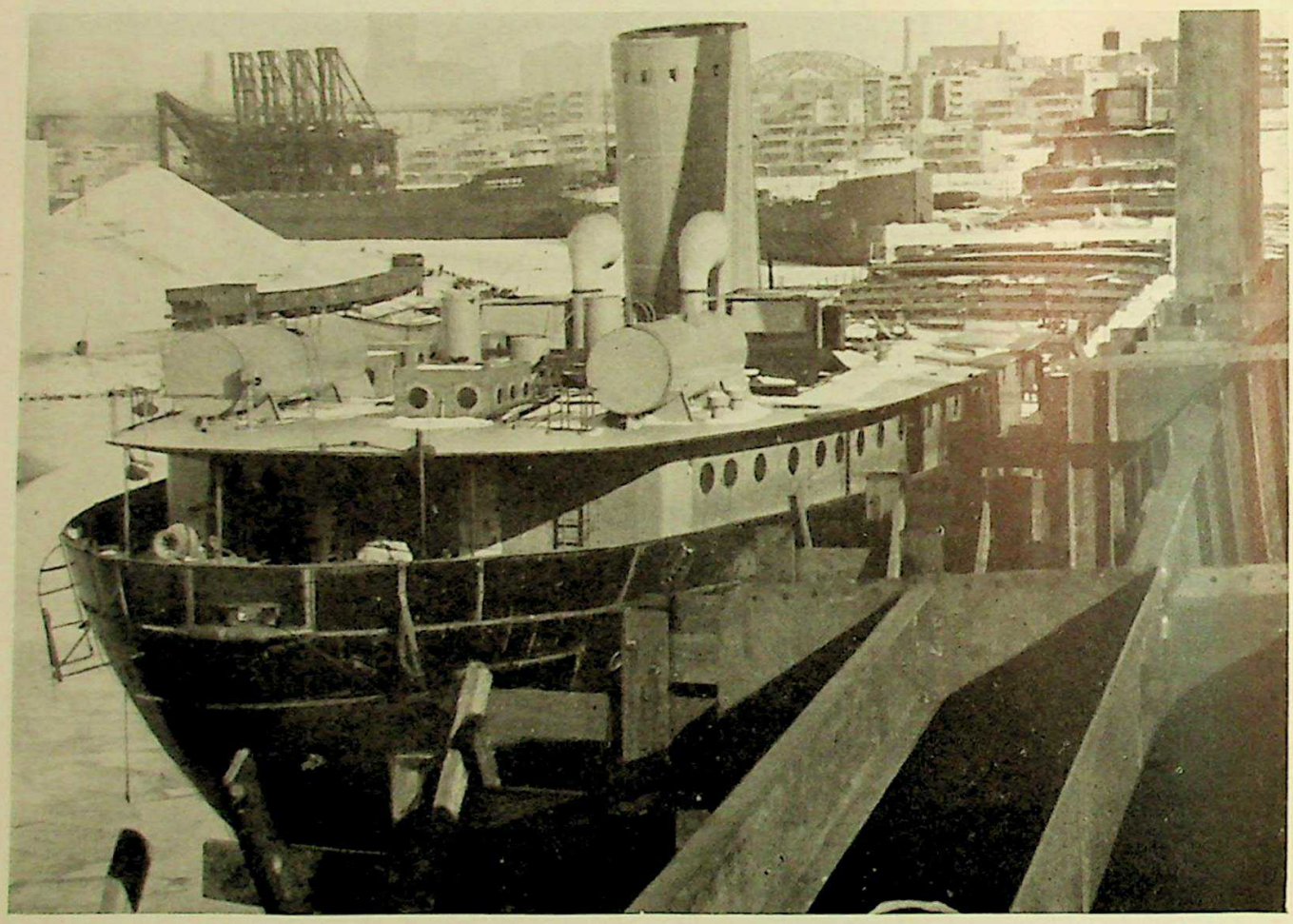


FIGURE 19—Ore Carrier at builder's dock after failure.

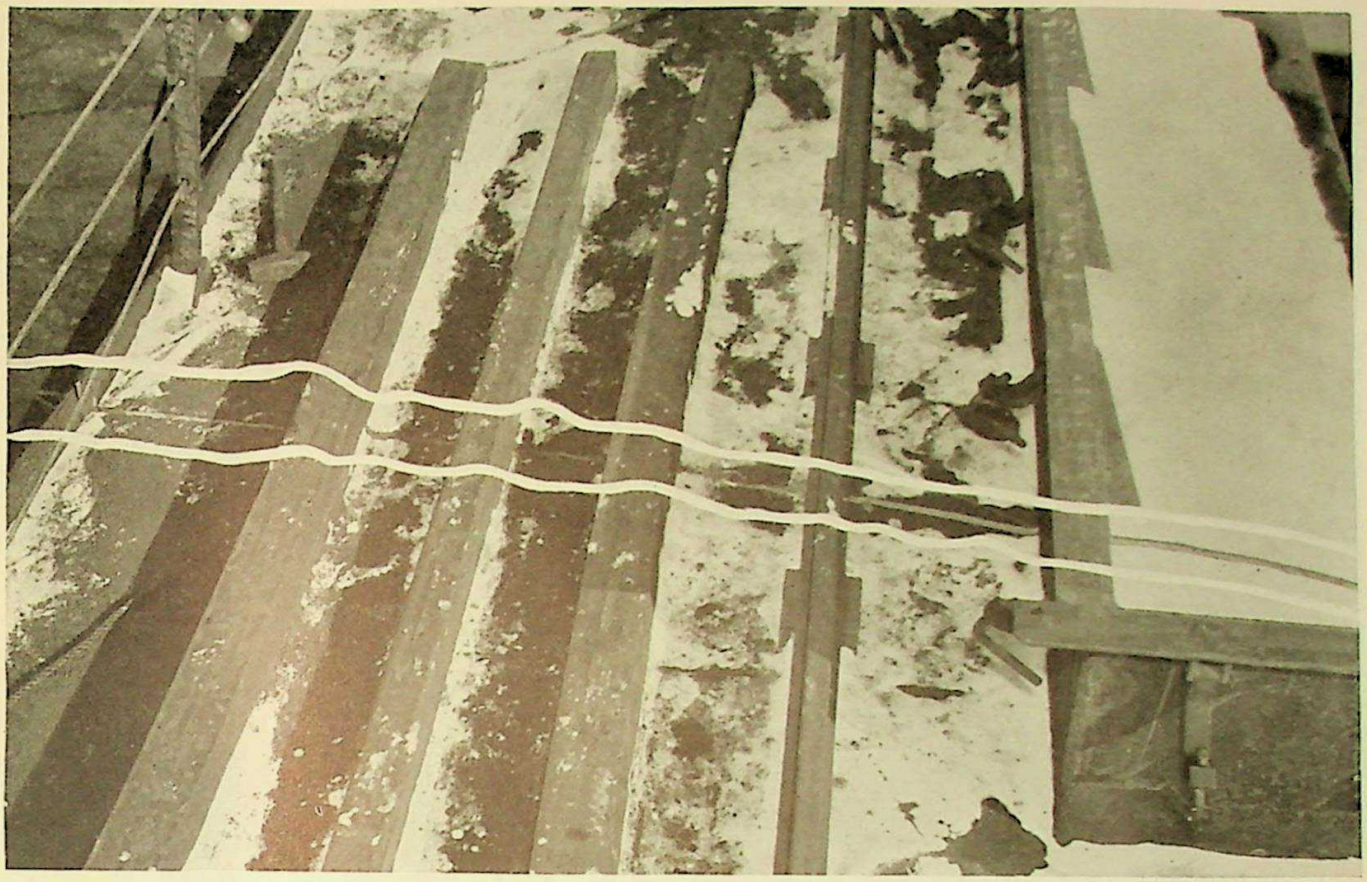


FIGURE 20—View of main deck, port side, showing extension of crack from hatch coaming to stringer. Three heavy steel bars used for emergency repair on each side of the deck appear in the photo.

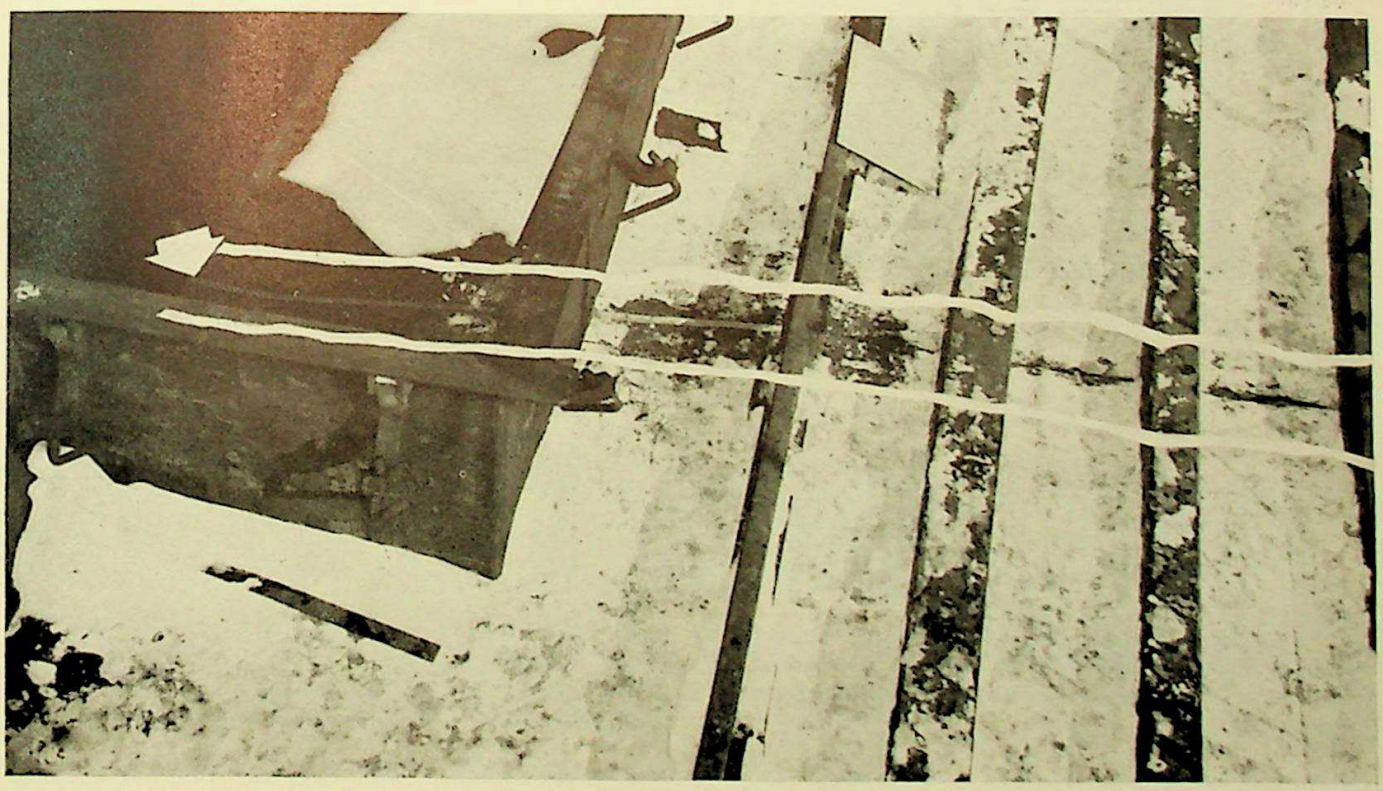


FIGURE 21—View of main deck, starboard side, showing fracture across deck. Arrow points to origin of fracture.

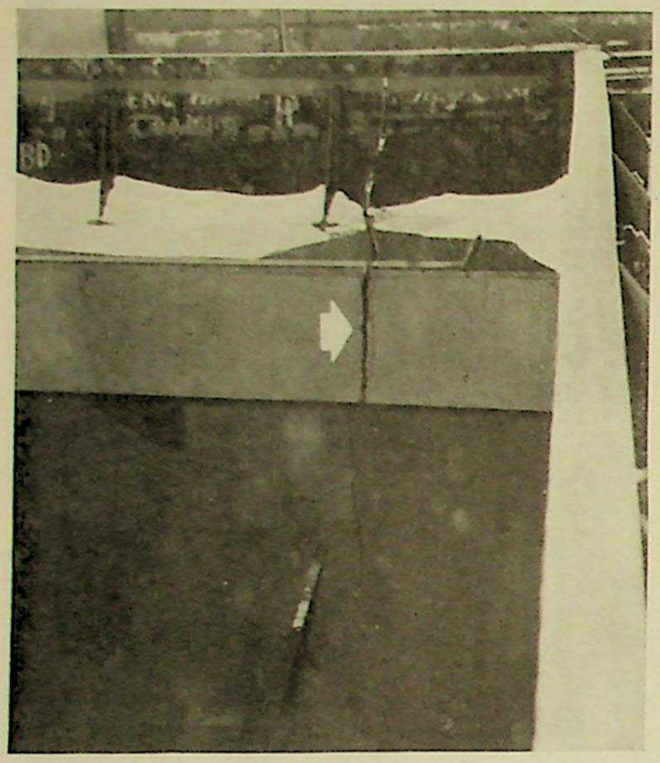


FIGURE 22—View of No. 9 hatch, starboard side, showing crack through coaming and down side of hopper. Arrow points to starting point of starboard fracture.

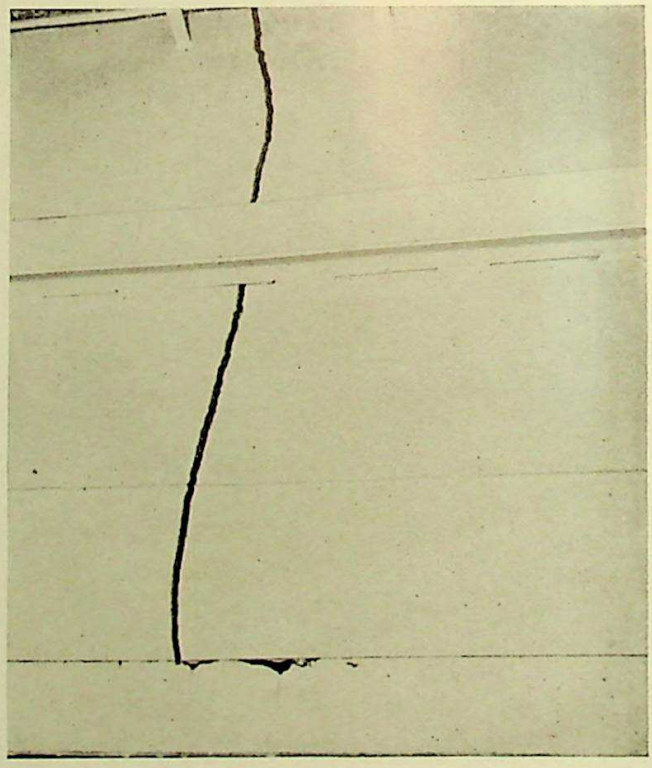


FIGURE 23—View of hopper side taken from starboard passageway between shell and side of hopper, looking inboard. View shows opposite side of fracture in Figure 22.

FIGURE 24—Detailed view of origin of fracture in butt weld of hatch side channel girder, port side. Herringbone pattern in deck plate (covered with snow) is clearly visible.

National Bureau of Standards Photo

FIGURE 25—Fractured 51 lb. deck plate showing poorly fused weld in upper flange of port side longitudinal. Herringbone arrows show fracture started at this defective weld.

TANK VESSEL, Z-ET1 TYPE

While at drydock in Seattle, several cracks were discovered on board this vessel. A few weeks prior to the discovery of the fractures, this tanker had sailed from San Pedro, Calif., to Puget Sound, Wash., loaded with 9,300 tons of fuel oil.

The extent of the damage on the vessel was:

(1) A crack 15 inches long in the upper edge of the starboard sheer strake, extending from the weld in the forward lower edge of the freeing port fashion plate. (See fig. 26.)

(2) A crack approximately 14 inches long in the manual weld in the main deck stringer plate extending inboard, on the starboard side. (See fig. 27.)

U. S. Coast Guard Photo

FIGURE 26—View of fracture in starboard sheer strake between frames 78 and 79.

(3) A crack in the bulwark plate running out of the upper forward corner of the freeing port at the after end of the recess for the accommodation ladder, starboard side. (See fig. 28.)

(4, 5) Two fractures in the manual welds of the bulwark cap at the after end of the recess for the accommodation ladder on the starboard side. (See fig. 29.)

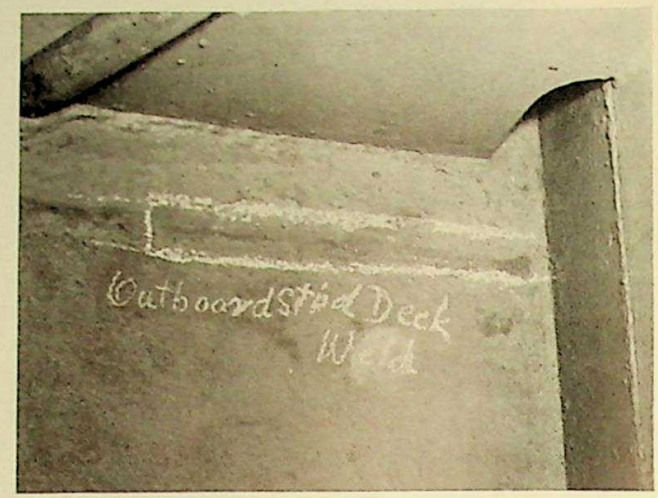
(6) A crack in the port bulwark cap in the manual weld at the after end of the recess for the accommodation ladder. (See fig. 30.)

(7) A crack in the manual weld of the boat deck stanchion No. 1, port side.

(8, 9) Cracks in superstructure supports Nos. 1 and 3 on starboard side.

(10, 11) Fracture in welding of the midship house to the deck at the forward port and starboard corners.

It will be noted that the majority of the fractures on the tanker occurred in manual welds, thus giving evidence of the defective welding on this vessel. Under unfavorable circumstances these fractures might have initiated a serious failure.



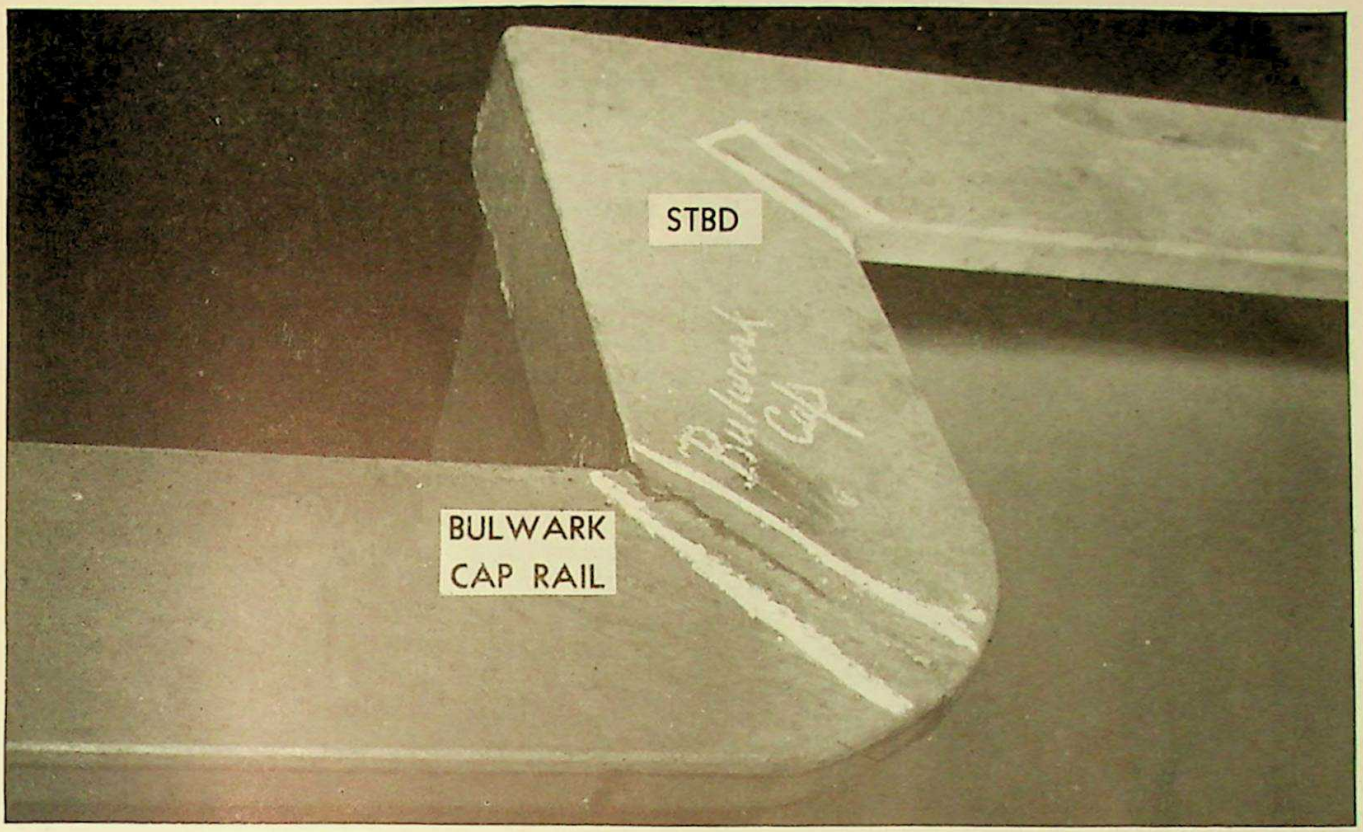
U. S. Coast Guard Photo

FIGURE 27—View of fracture in manual weld on outboard starboard side of upper deck.

The cost of repairs on this tanker was $300.

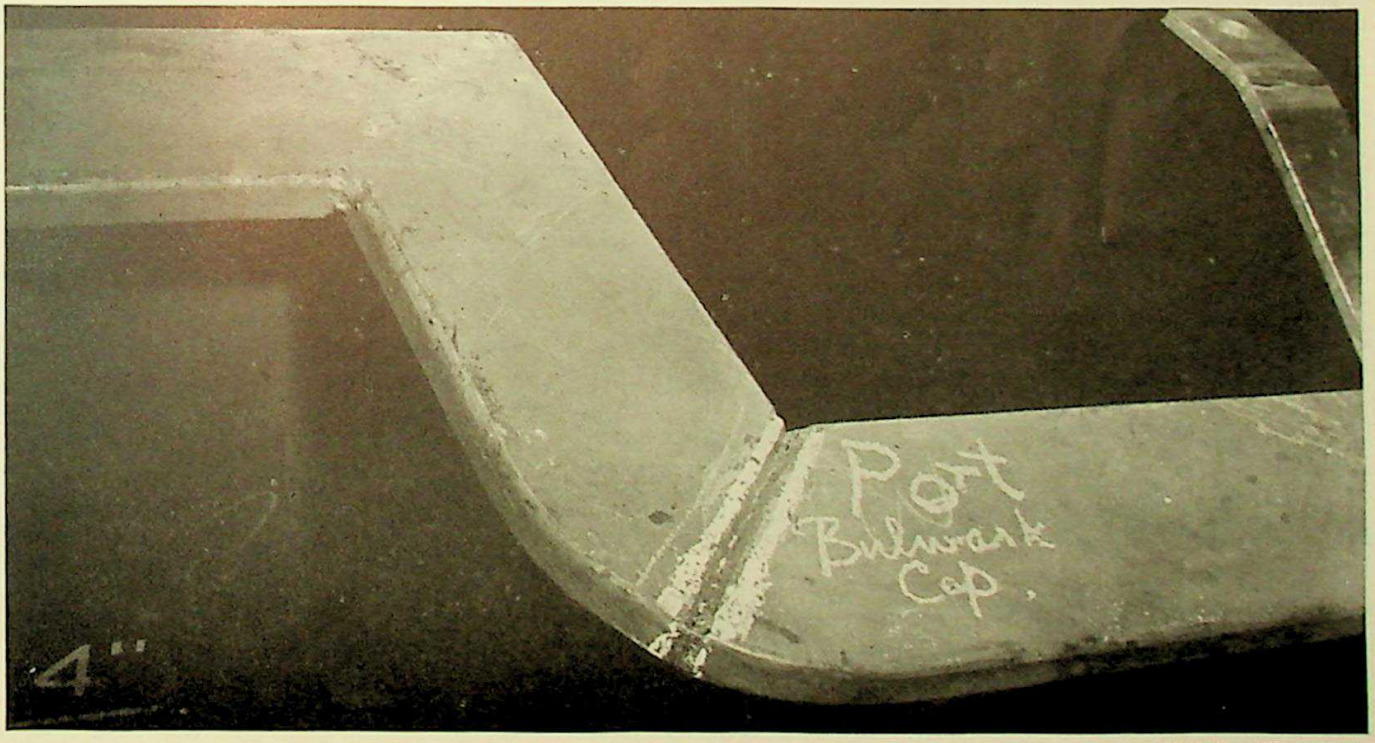
U. S. Coast Guard Photo

FIGURE 28—Fracture in upper forward corner of bulwark freeing port, after end of accommodation ladder recess, starboard side.



U. S. Coast Guard Photo

FIGURE 29—Two fractures in manual welds of bulwark cap at after end of accommodation ladder recess, starboard side.



U. S. Coast Guard Photo

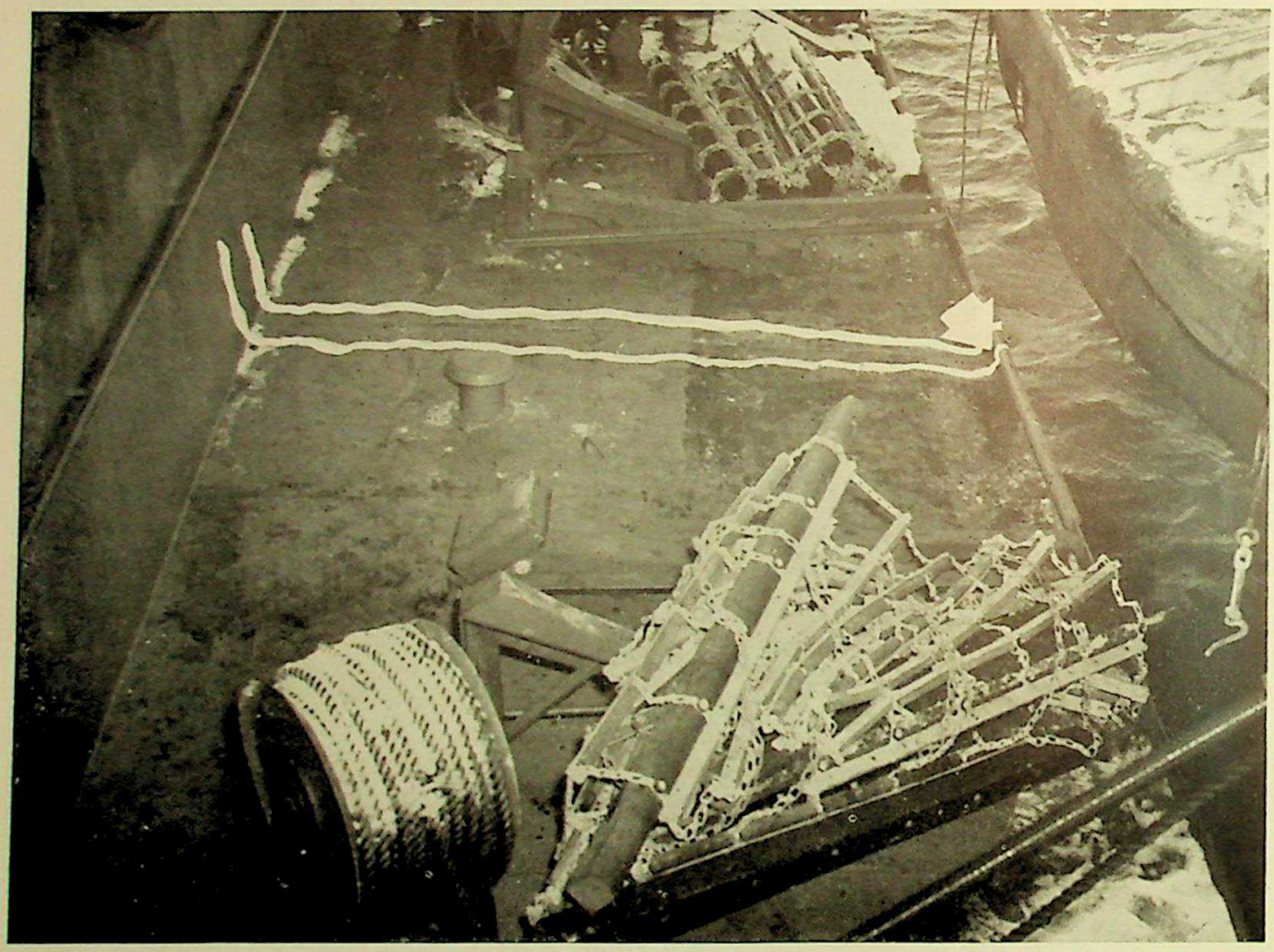
FIGURE 30—View of fracture in port bulwark cap at after end of recess for accommodation ladder.

CARGO VESSEL, EC2 TYPE

With considerable roar and crash and a loud report which sounded like an explosion, this ship shook violently and fractured. The vessel was lying at anchor in a calm sea in Boston Harbor, fully loaded and scheduled to sail.

The fracture started in a defective butt weld in the apron plate located under the chafing pipe on the port side of the boat deck. The crack extended across the deck and downward about 18 inches, ending in the frame of a porthole in the main deck house (figs. 31, 32). The branch of the fracture which travelled upward terminated in the boat deck house about 7 feet up from the deck (fig. 33). Examination of the source of fracture revealed an old break in a faulty weld which apparently formed a notch and served as a starting point of fracture (figs. 36, 37).

While under repair, this vessel remained out of service for 7 days. The cost of repairs necessitated by the failure was $2,300.

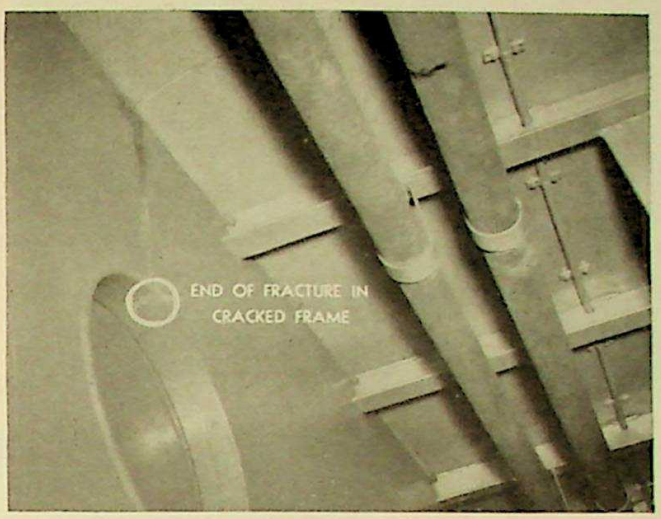


U. S. Coast Guard Photo

FIGURE 31—View of fracture across boat deck, port side, in way of No. 2 lifeboat. Arrow points to origin of fracture in curtain plate at edge of deck.

FIGURE 32—View looking from underside of boat deck, showing downward course of fracture and its termination in porthole frame on main deck house.

U. S. Coast Guard Photo



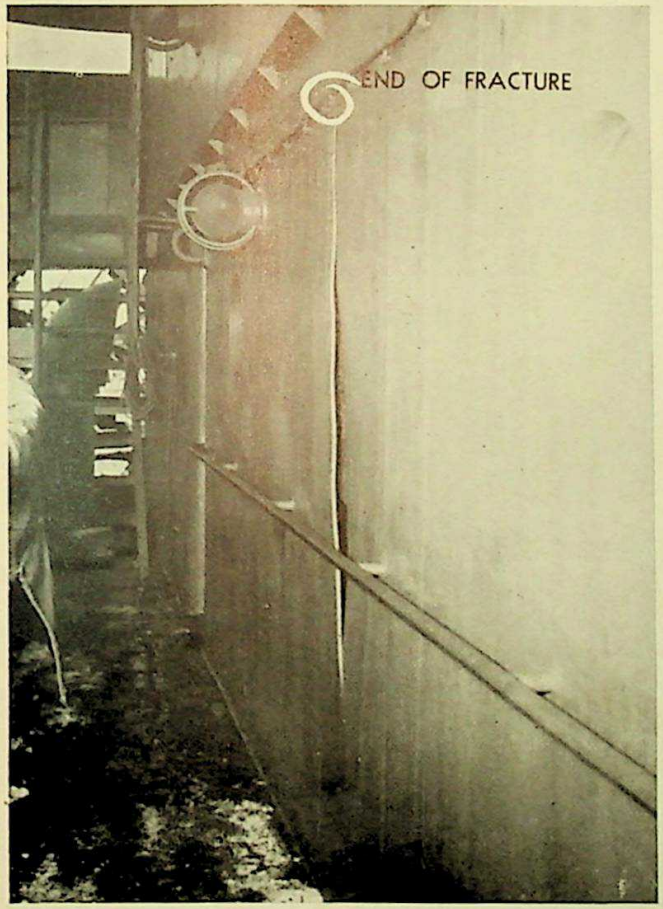


FIGURE 33—View of crack in boat deck house ending in seam of plating about 6 inches below bridge deck.

U. S. Coast Guard Photo

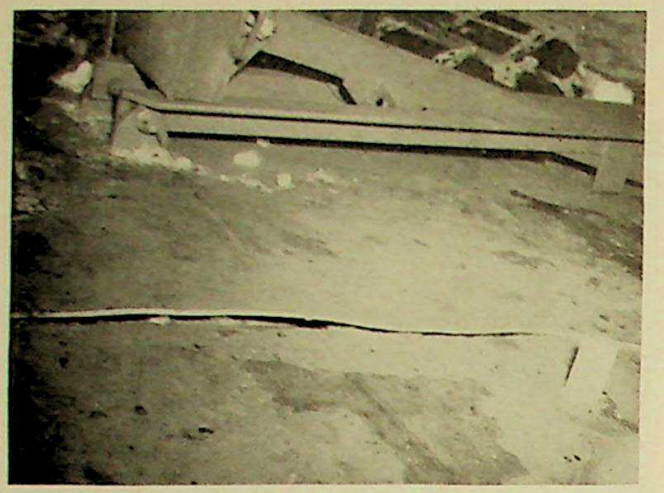


FIGURE 34—Close-up view of crack across boat deck.

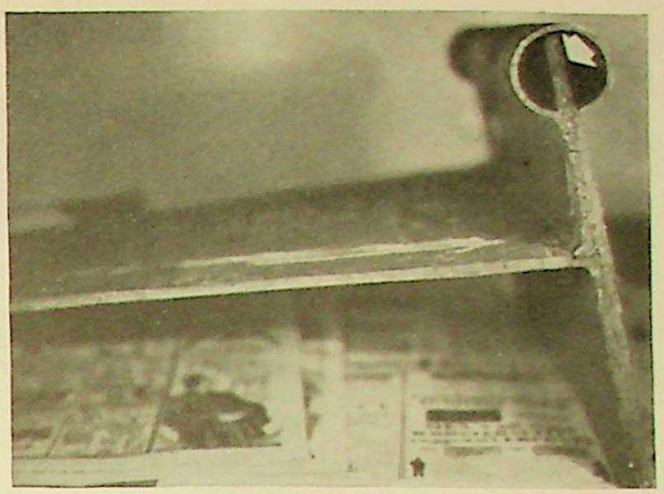
U. S. Coast Guard Photo

U. S. Coast Guard Photo

FIGURE 35—Close-up view of origin of fracture in boat deck. Chalk lines mark area from which specimens of steel plates were removed.

FIGURE 36—Deck stringer plate, apron plate, and butt weld which caused ship failure. Arrow points to starting point of failure.

U. S. Coast Guard Photo



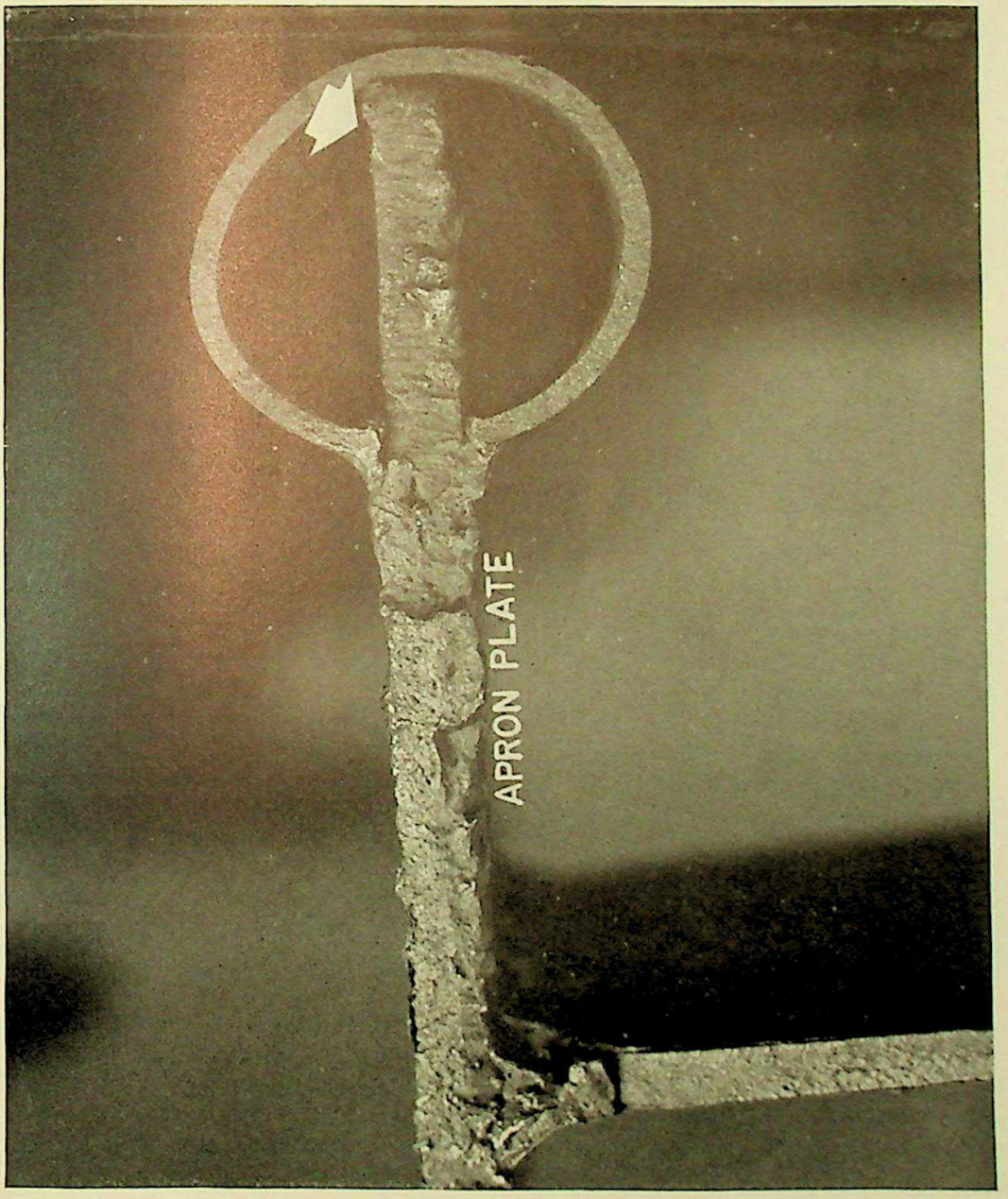
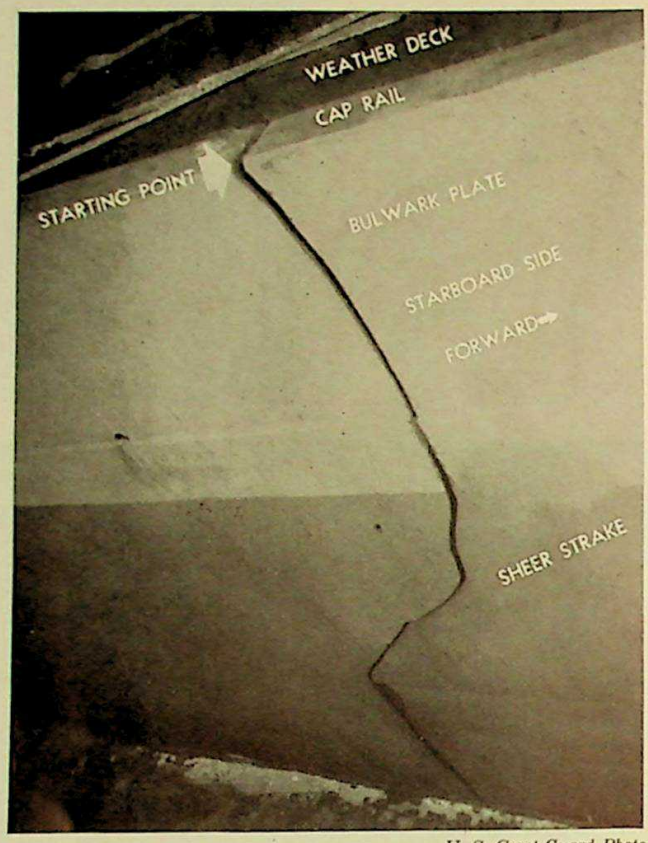


FIGURE 37.—Close-up view of origin of fracture.

U. S. Coast Guard Photo

CARGO VESSEL, C2 TYPE



U. S. Coast Guard Photo

FIGURE 38—View of fracture which originated in cap rail of bulwark, starboard side, showing extent of crack down side of vessel below water line. Arrow points to source of fracture.

This cargo vessel sustained serious fractures in way of No. 3 and No. 4 hatches while in convoy about 225 miles east of Ambrose Channel in the North Atlantic. Permission was received to turn back from convoy and put into port for repairs. Subsequent to the arrival of the vessel in the repair yard, many other small cracks were found. Only the major fractures are discussed and illustrated in this booklet.

At 1 a. m. on the night of the failure, there was a major cracking in way of No. 3 hatch; the vessel shook and was thrown 10° off course. Three and three-quarters hours later while the ship was en route back to port a fracture occurred in way of No. 4 hatch. On both occasions a loud report was heard. Heavy wire ropes were reeved around the midship deck-house structure and the house structure forward of No. 3 hatch to hold the damaged vessel together. Undoubtedly the 1,000 to 1,500 tons of sea water which entered the No. 3 hold through the fracture had already relieved the tendency to hog and also helped to hold the ship together.

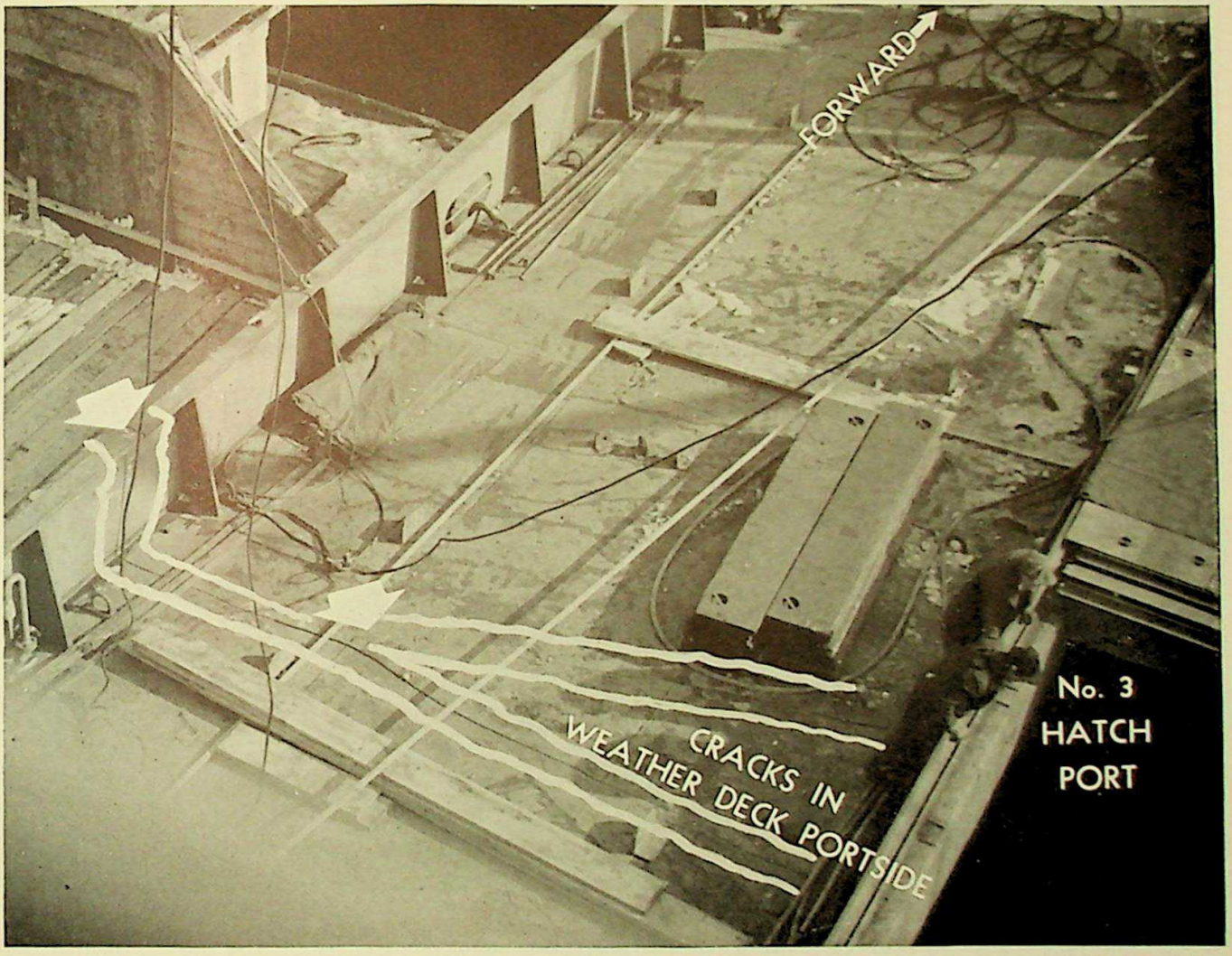
There were seven major fractures on this vessel when she put in to the repair yard. One of the most serious cracks started in a butt weld in the cap rail of the bulwark in way of No. 3 hatch on the starboard side. It extended down through the bulwark, into the sheer and stringer plates, and down the side shell below the water level. (See fig. 38.) In passing the second deck the crack broke inboard across the deck to the hatch. Inboard from the bulwark cap rail, the crack traveled across the weather deck to the starboard hatch side coaming, which it severed completely in a vertical fracture. Secondary cracks were found also to have their source in defective welds.

On the port side of the vessel in way of No. 3

hatch there was an almost identical crack which originated likewise in a butt weld in the cap rail of the bulwark. (See figs. 41 and 42.) It crossed the weather deck and broke vertically into the port hatch side coaming for several inches. (See figs. 39 and 40.) The second deck was severed for only a few feet by this crack.

At a point just 8 or 10 inches forward of this crack on the weather deck another fracture occurred which started in a welded seam about 5 feet inboard of the deck edge and extended inboard to the hatch side coaming. (See fig. 39.)

Still another crack in way of the No. 3 hatch on the port side started in a weld cavity at the hatch cover lug strip. The hatch side coaming was completely fractured in a vertical line, but the fracture did not break into the deck for any significant distance.



U. S. Coast Guard Photo

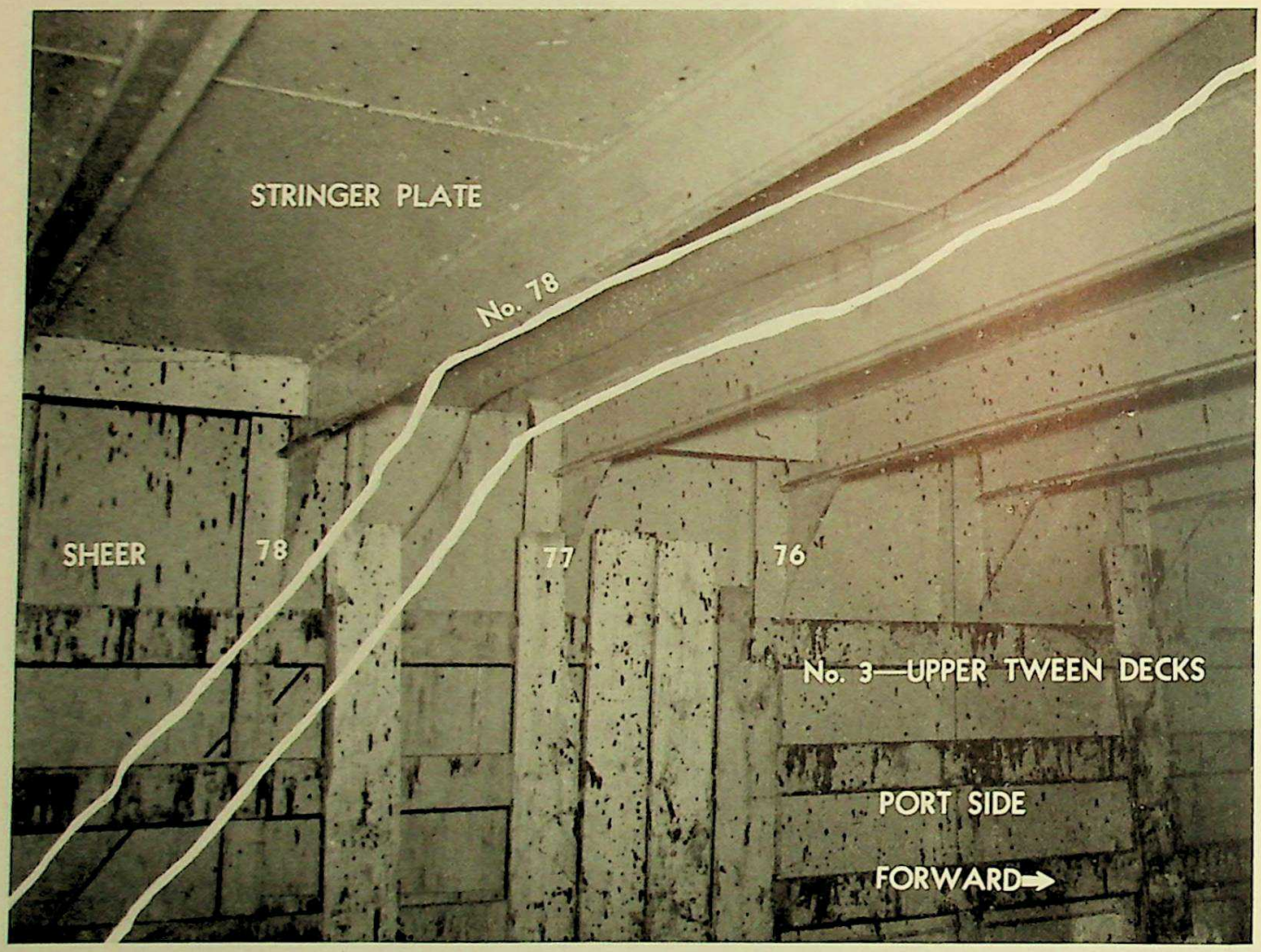
FIGURE 39—View of port side of vessel, showing one crack running from cap rail in bulwark to #3 hatch side coaming, and another crack running from its source in deck to hatch side coaming. Arrows point to origins of fractures.

The fracture in way of No. 4 hatch started in a butt weld in the port bulwark cap rail. (See figs. 43, 44.) The crack extended down through the bulwark and into the sheer strake and side shell. From the bulwark, it travelled across the weather deck to the hatch side coaming and severed it completely.

Less serious fractures were located in the side coaming of No. 3 hatch on the port side, and in the weather deck just a few inches forward of the deck house on the starboard side.

The welds in which all these fractures originated revealed either weld cavities or lack of penetration of the weld metal in every case, thereby giving evidence that defective welding was one of the most important factors contributing to the failure of this vessel.

The ship remained out of service for 54 days while under repairs. The total cost of these repairs was $217,137.

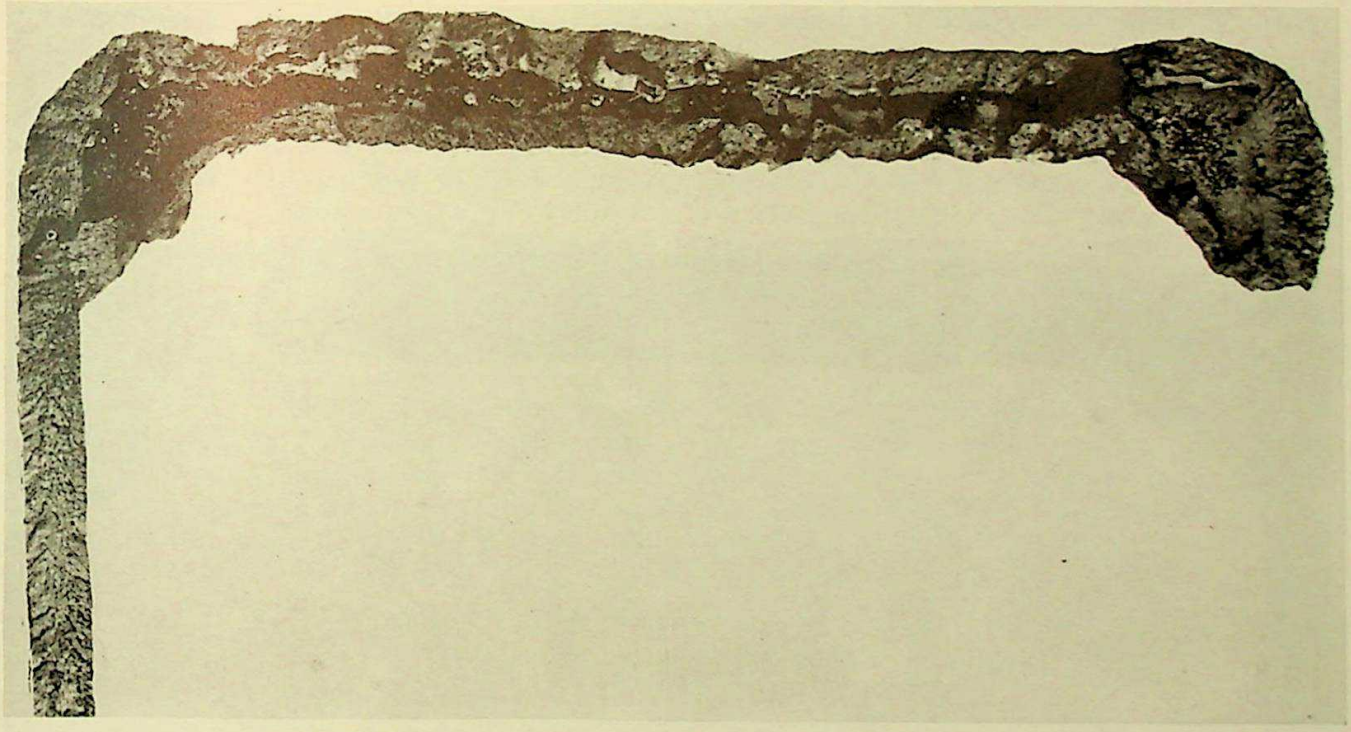


U. S. Coast Guard Photo

FIGURE 40—View of under side of weather deck on port side of vessel, showing crack in deck and side shell.

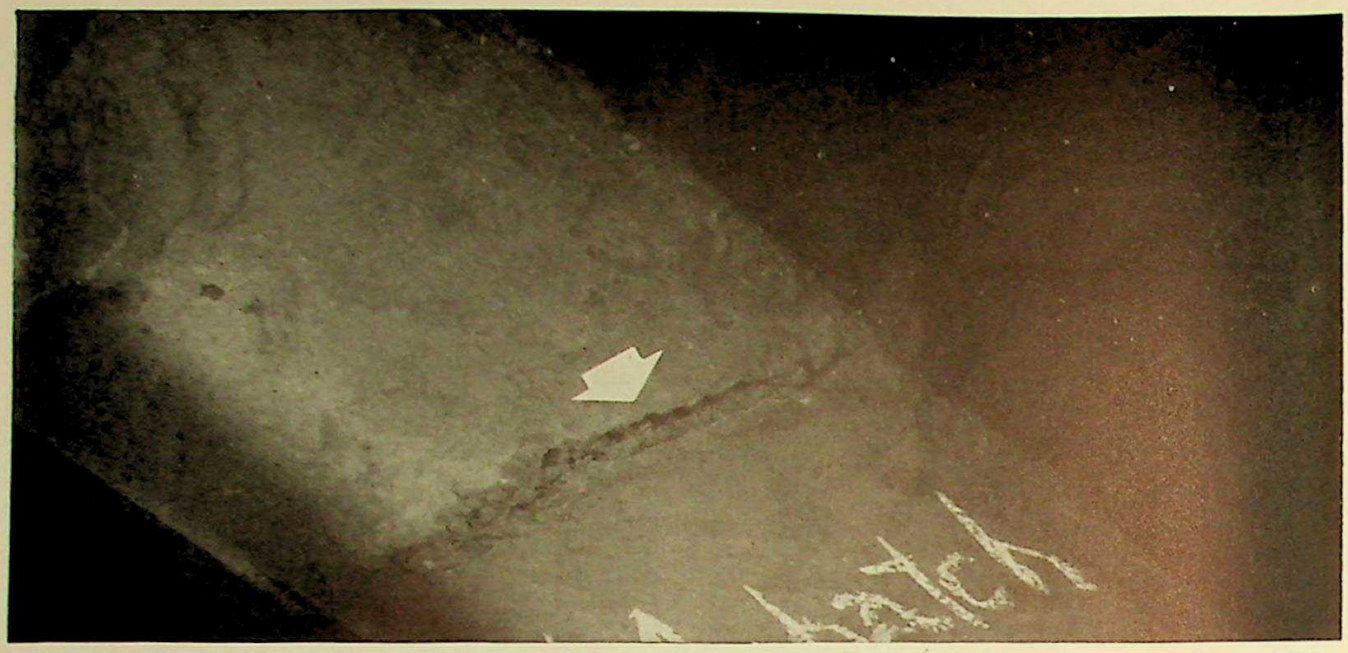
FIGURE 41—View of origin of fracture in bulwark cap rail, opposite No. 3 hatch, port side looking forward. A similar fracture occurred in the bulwark cap rail, starboard side, opposite No. 3 hatch. (See Fig. 38)

U. S. Coast Guard Photo



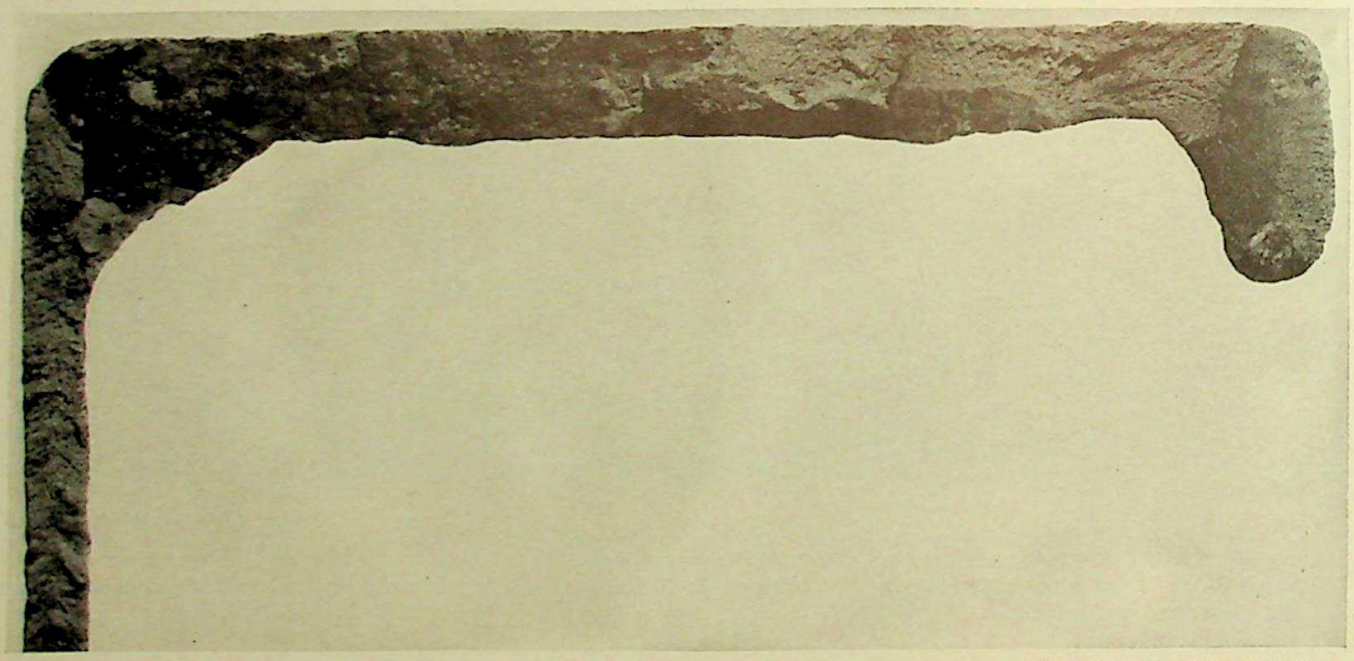
National Bureau of Standards Photo

FIGURE 42—View of defective butt weld in bulb angle of port bulwark cap rail shown in Figure 41. Note small area fused by welding. Dark areas on lower edge of section shown in photograph contain red lead which lodged in weld during construction of vessel.



U. S. Coast Guard Photo

FIGURE 43—View taken on port side of vessel, looking aft. Origin of fracture in bulwark cap rail opposite No. 4 hatch.



National Bureau of Standards Photo

FIGURE 44—Defective weld in bulb angle of bulwark cap rail shown above. Note areas of non-fusion in weld, and herring-bone pattern on plate (lower left) pointing to origin of fracture.

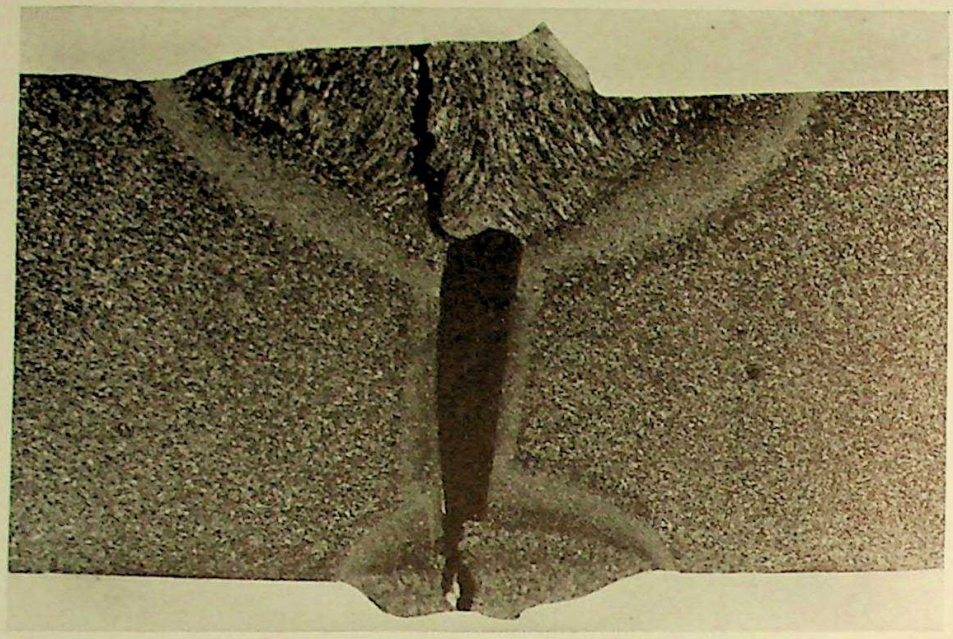
CAUSES OF DEFECTIVE WORKMANSHIP AND CURES

In the foregoing chapters, the illustrations and descriptions have demonstrated clearly and conclusively the need for completely sound welds. They have shown that the metal deposited by the welder must be as sound as is the surrounding steel. Furthermore, a weld must join two or more pieces of steel so firmly that they become in fact one piece of metal throughout. In these photographs it has been possible for the reader to see for himself how each defective weld is a potential source of fracture. Equally important with recognition of a faulty weld and the realization of its possible consequences is a clear understanding of the deviations from proper welding procedure which cause defects.

A welding operator cannot be compared with an automatic welding machine which can be adjusted by dials on a control panel to produce welds of quality at so many inches a minute, with the desired penetration, proper width, reinforcement and contour. Being a mortal, the welder is affected by the margin of human error and is subject to human failings. Nearly all welders—like all other craftsmen, or even golfers or pilots—reach a stage in their experience when they believe they know a lot more about their work than they actually do. At this stage they often resent offers of help or advice because they are overconfident. When a welding operator reaches this period in his career, he becomes a problem to the welding supervisor, and may easily become an unwitting saboteur. His mistakes sometimes result in costly repairs and under unfortunate sets of circumstances have led even to complete ship failures.

Some welding operators never question their own ability to make a sound weld regardless of the condition of the joint to be welded. It is impossible for a welding supervisor to inspect each joint for alignment, root opening or sound tacks. This responsibility is the welder's, for he is in the best position to examine these as he makes the weld. Should the parts to be welded be out of line, or the root opening be too large to insure a sound weld, or the tacks be cracked, the operator should call these conditions to the attention of the supervisor so that corrections can be made.

Illustrated below are the various types of defects which result from imperfect workmanship. All photographs are of defects found on ships in service. In addition, there is included a list of the faulty practices which cause these defects. Incorrect joint design, one of the most important causes of defective welding, is not mentioned below because it is the responsibility of the designer of the vessel and not of the welder. Each defect shown in the photographs is not necessarily attributable to all the malpractices listed as the causes of that particular defect. In some cases only one of the causes listed led to the defect illustrated, and in other cases one or more or all of the causes set forth were responsible for the defect photographed.



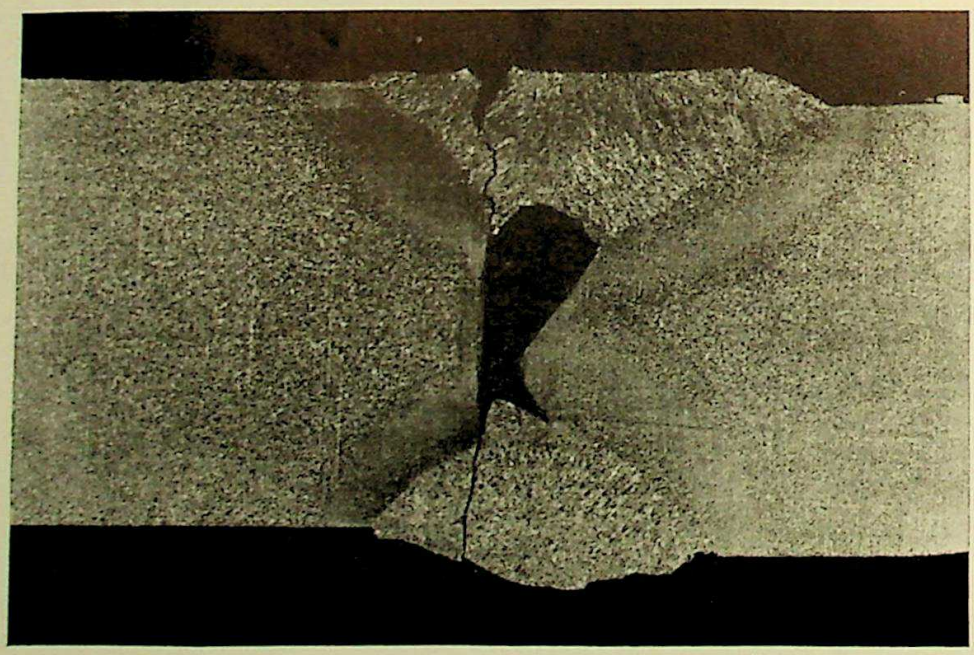
American Bureau of Shipping Photo

FIGURE 45—Saddle Weld—3X Actual Size—Liberty Vessel.

Saddle Welds (figs. 45, 46)

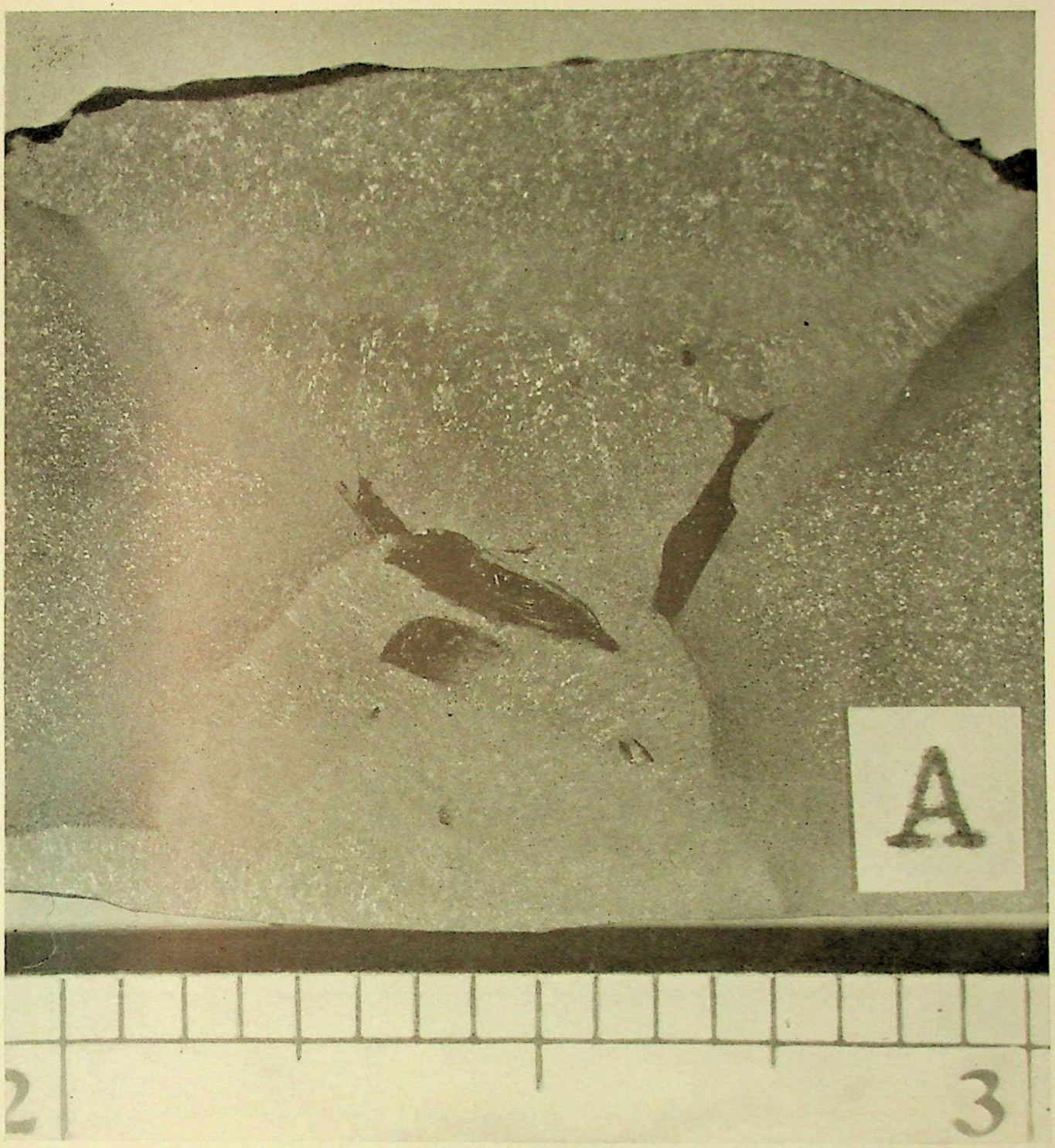
Causes:

1. Improper plate edge preparation.
2. Improper chipping of welding groove.
3. Too close fit-up.
4. Use of wrong electrode.
5. Incorrect welding machine setting.
6. Incorrect speed of welding.



American Bureau of Shipping Photo

FIGURE 46—Saddle Weld—3X Actual Size—Liberty Vessel.



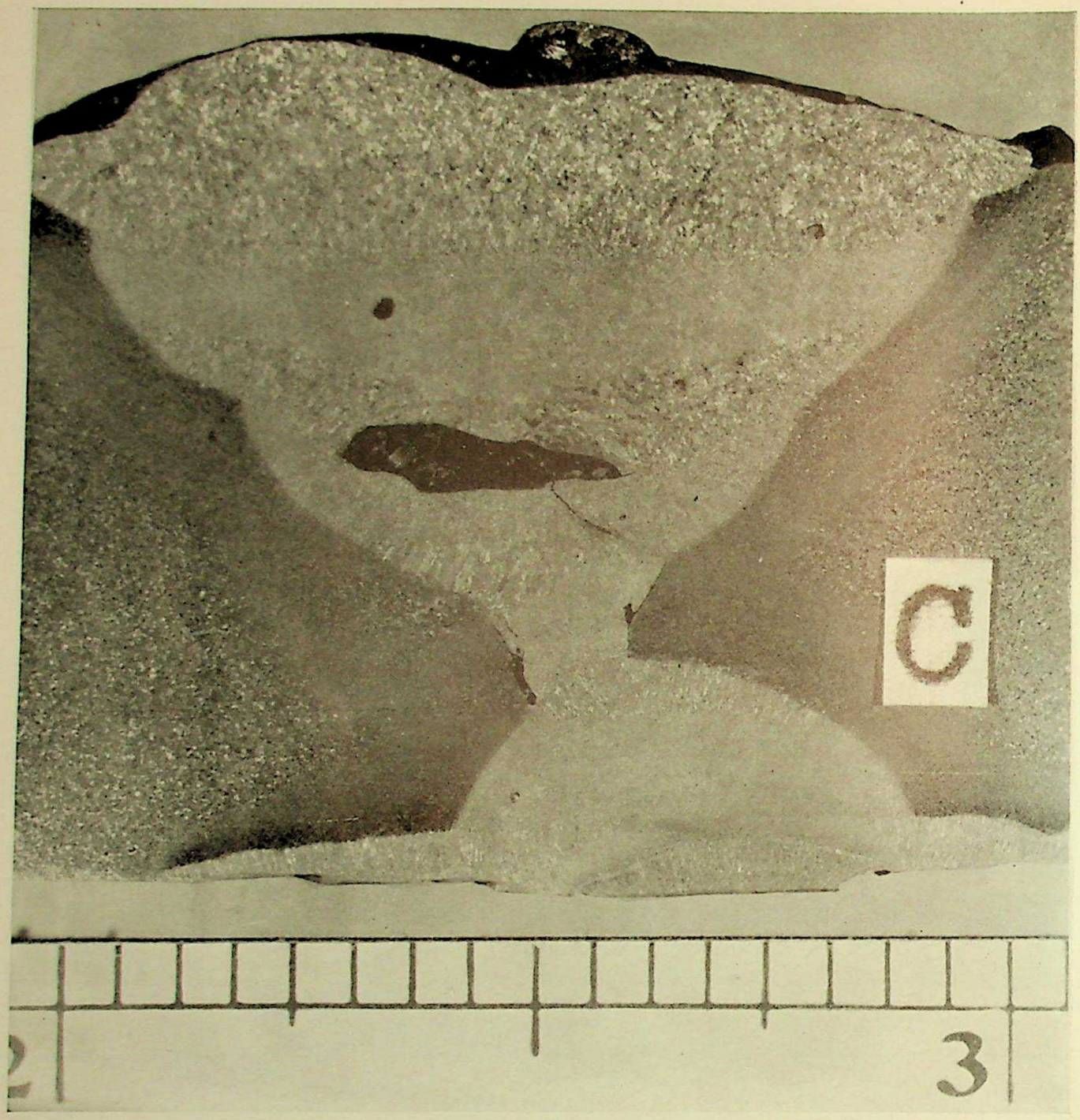
U. S. Navy Photo

FIGURE 47—Cavities in Weld—Magnified 6X, etched. Hull Plate—T2 Type Tanker.

Cavities in Weld (figs. 47, 48)

Causes:

1. Improper plate edge preparation.
2. Improper chipping of welding groove.
3. Too close fit-up.
4. Insufficient cleaning of welding groove.
5. Use of slugs.

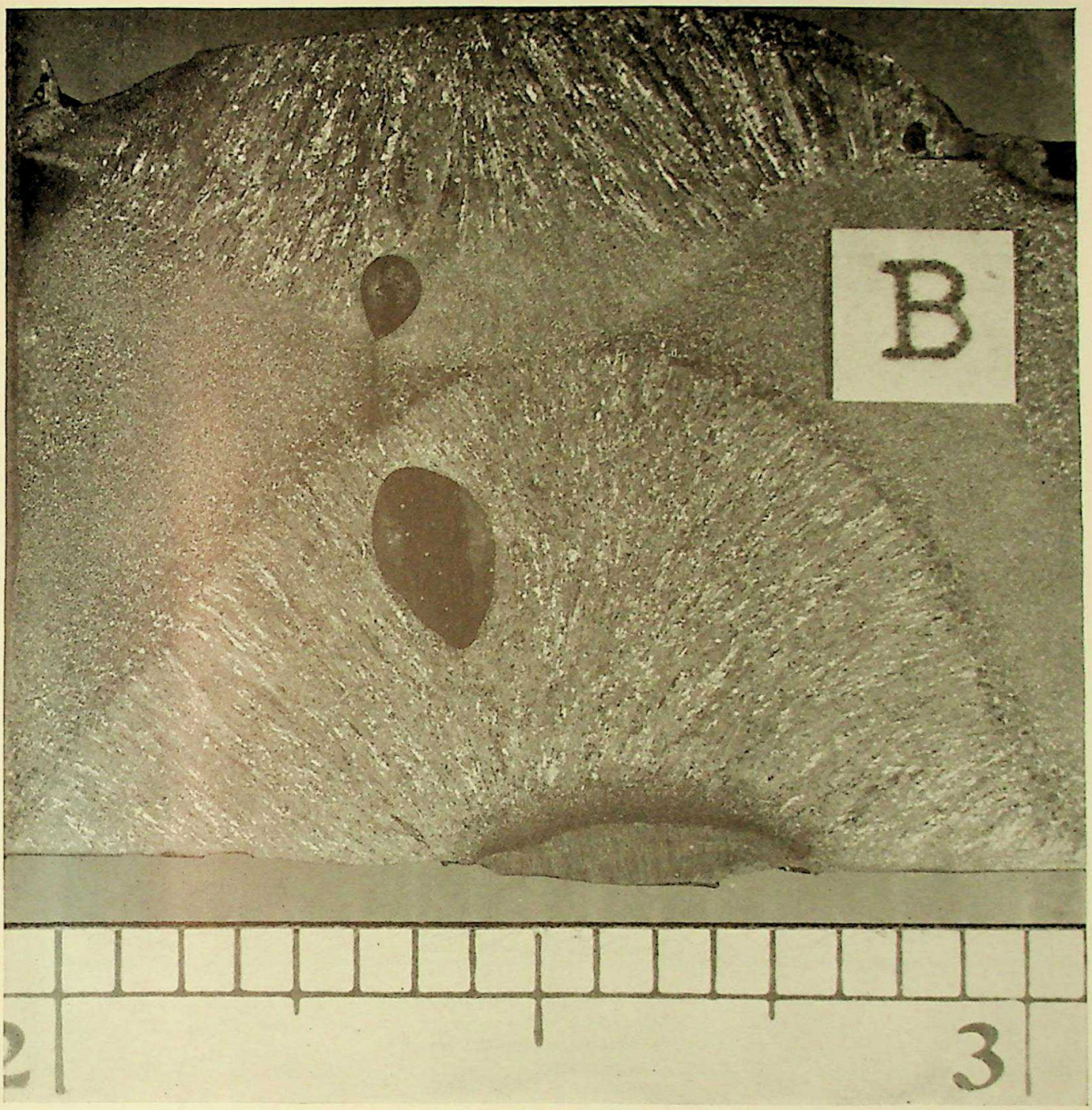


U. S. Navy Photo

FIGURE 48—Cavities in Weld—Magnified 6X, etched. Hull Plate—T2 Type Tanker.

Cavities in Weld (figs. 47, 48)—Continued

6. Failure to back chip.
7. Chipping with diamond-pointed tool.
8. Lack of penetration due to excessive speed of welding.
9. Use of oversized electrode.
10. Use of wrong type of electrode.
11. Incorrect setting on welding machine.



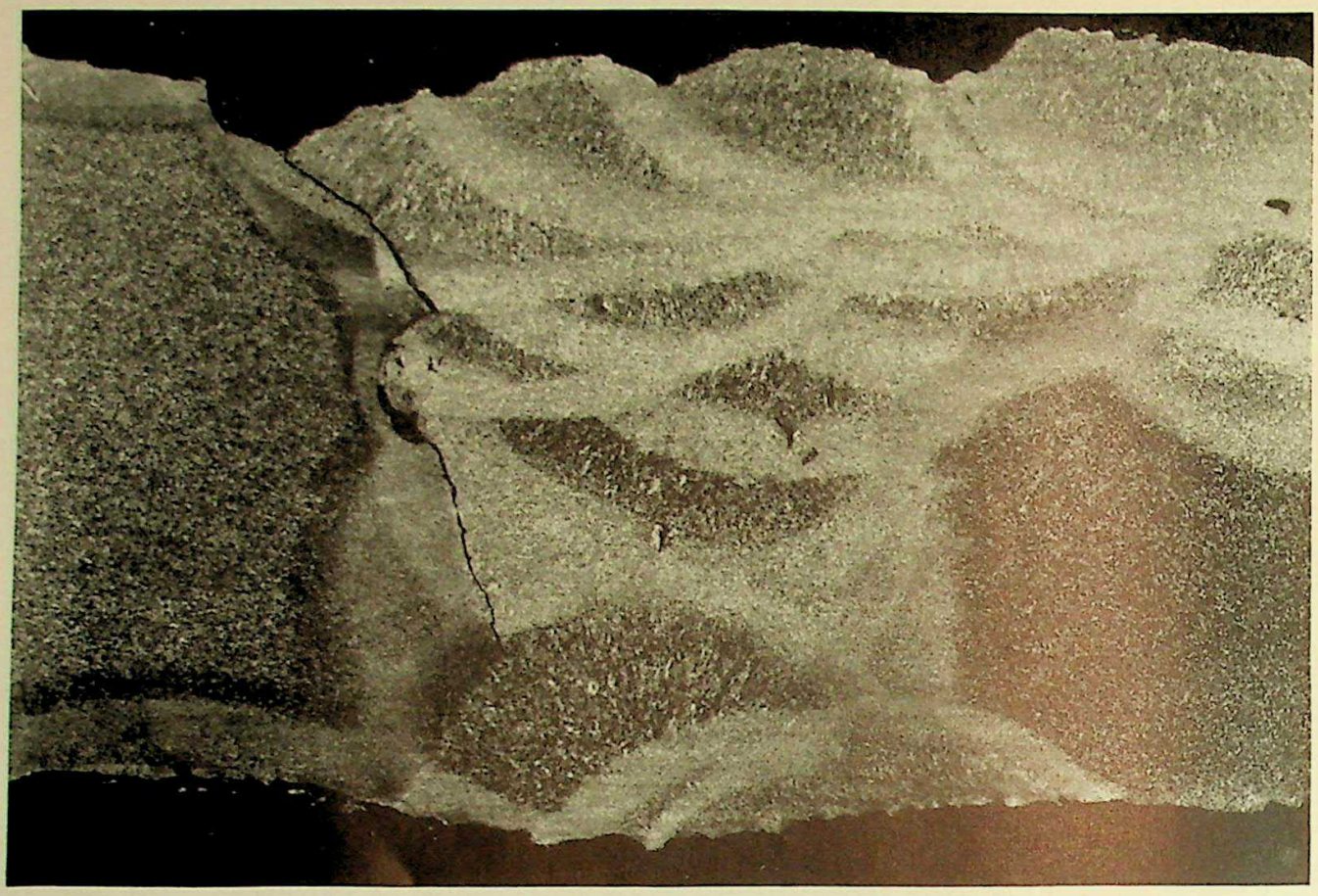
U. S. Navy Photo

FIGURE 49—Slag and Dirt in Weld, Magnified 6X, etched. Hull Plate—T2 Type Tanker.

Slag and Dirt in Weld (fig. 49)

Causes:

1. Improper cleaning of joint.
2. Failure to clean beads between passes.
3. Oversized root opening, no backing.
4. Incomplete chipping or back chipping.
5. Excessive speed of welding.
6. Incorrect setting on welding machine.
7. Arc too long.
8. Electrode too dry.



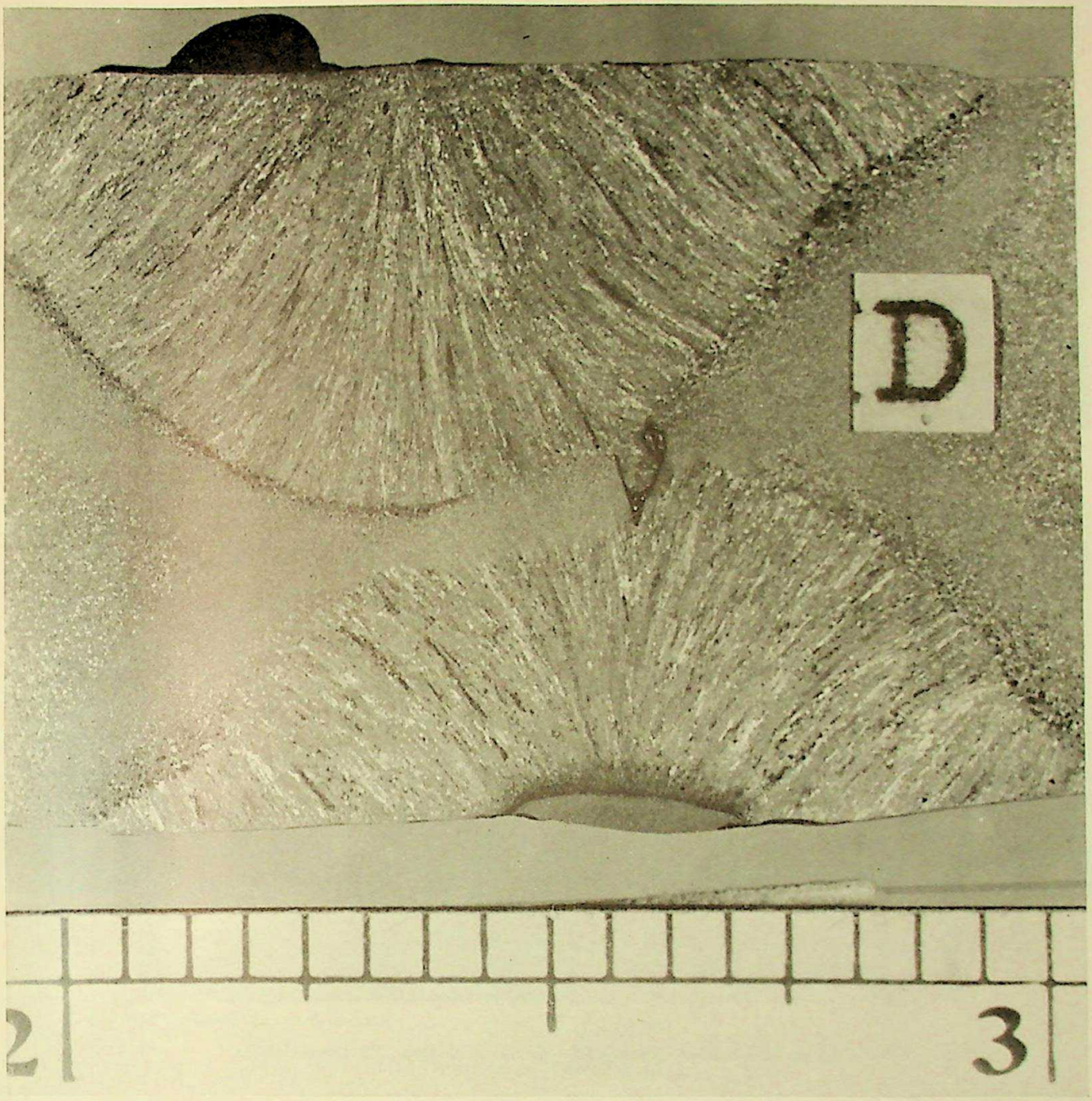
American Bureau of Shipping Photo

FIGURE 50—Shrinkage Crack—3X Actual Size—T2 Type Tanker.

Shrinkage Cracks (fig. 50)

Causes:

1. Failure to fill in crater at end of weld.
2. Failure to chip out crater at end of step.
3. Failure to follow welding sequence.
4. Neglecting to preheat when needed.
5. Use of wrong electrode.
6. Too close fit-up.
7. Incorrect welding machine setting.



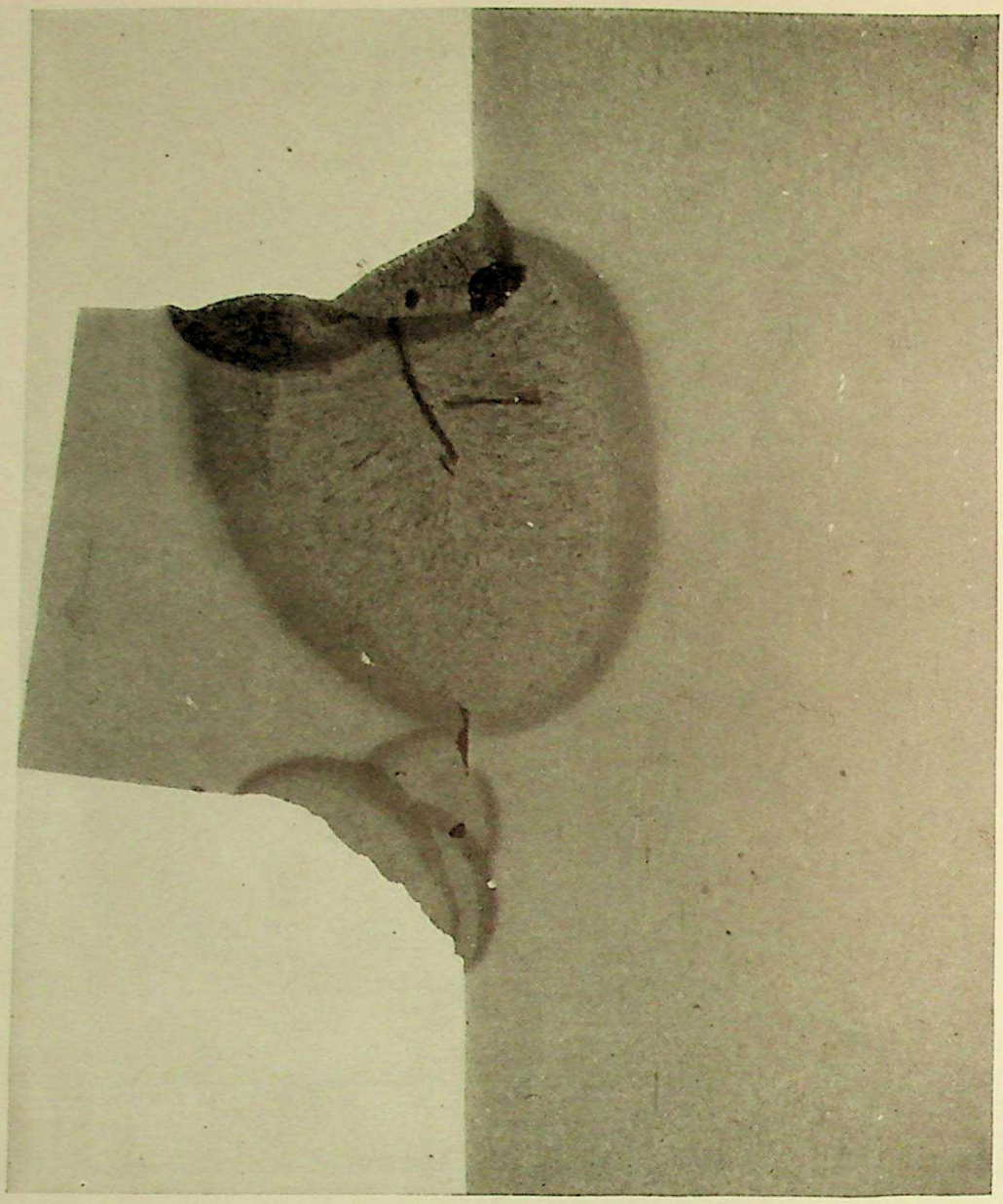
U. S. Navy Photo

FIGURE 51—Other Nicks and Cracks in Weld—Magnified 6X, etched—Hull Plate—T2 Type Tanker.

Other Nicks and Cracks in Weld
(fig. 51)

Causes:

1. Weld too small for joint.
2. Peening first pass.
3. Improper chipping at weld crossing.
4. Failure to follow welding sequence.
5. Use of wrong electrode.
6. Too close fit-up.
7. Incorrect welding machine setting.
8. Failure to follow groove with automatic machine.



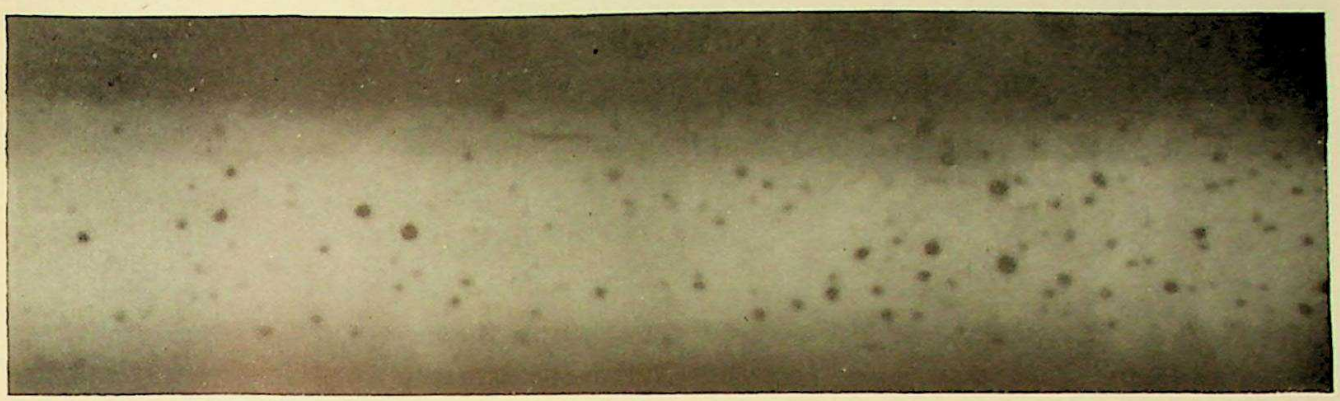
National Bureau of Standards Photo

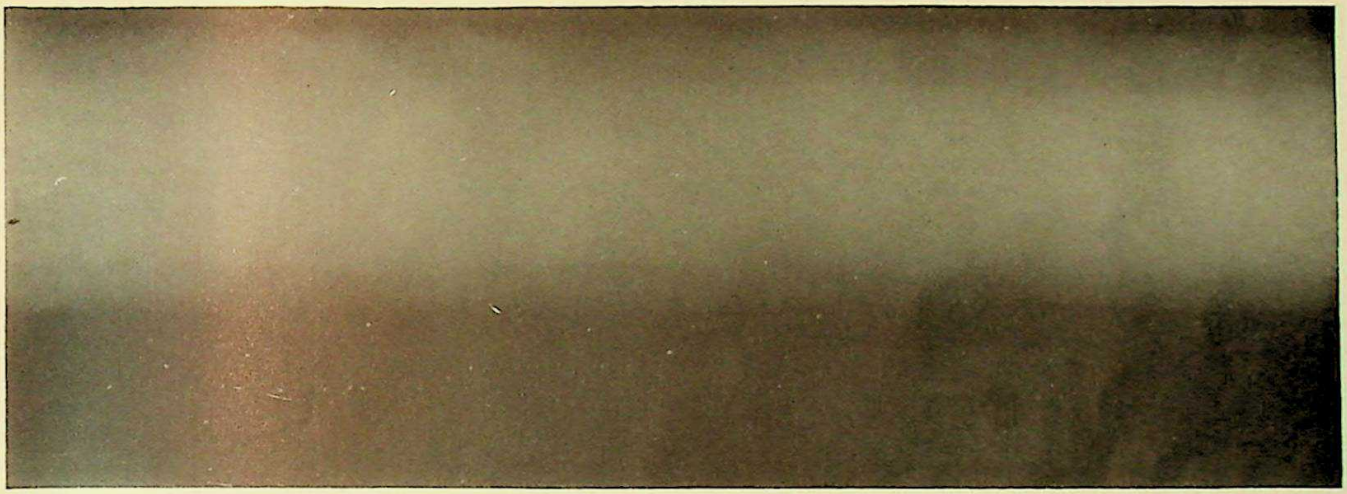
FIGURE 52—Buried Crack—X1—Gunwale of Type T2 Type Tanker.

Buried Crack, Cavities, etc. (Fig. 52)

Causes:

1. Bobbing and caulking to stop leak when testing.
2. Welding over cracks instead of chipping them out.





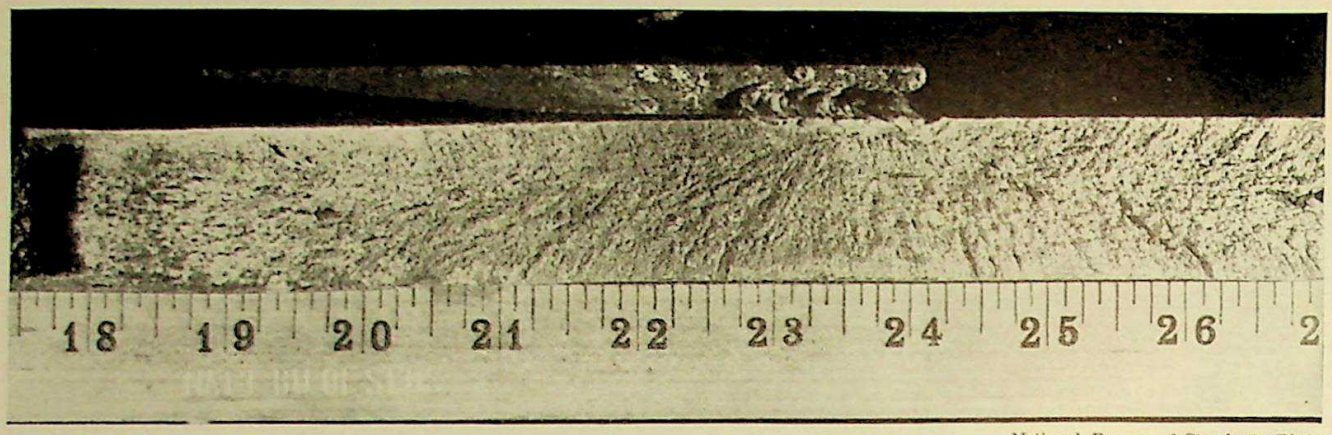
U. S. Navy Photo

FIGURE 53—(Above): Porosity in weld. X-ray photograph of weld in submarine shell.
(Below): X-ray of sound weld is included for comparison.

Porosity in Weld (Fig. 53)

Causes:

1. Use of wrong electrode.
2. Too wide fit-up.
3. Arc too long or too short.
4. Groove wet when welded.
5. Excessive speed of welding.
6. Damp electrode.
7. Incorrect setting on welding machine.



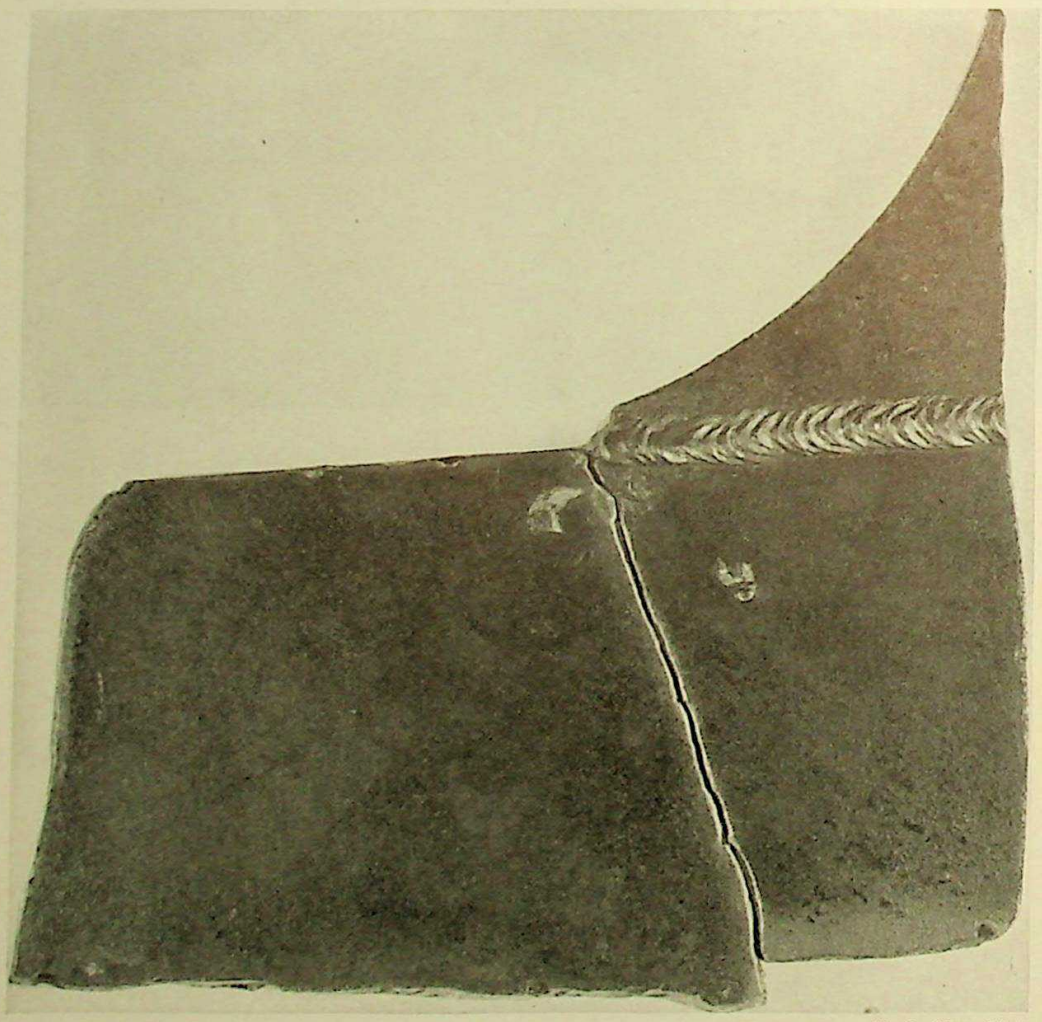
National Bureau of Standards Photo

FIGURE 54—Nicks and Notches Not in Weld. Clip Attached to Shell Plating.

Nicks and Notches Not in Weld (Figs. 54, 55)

Causes:

1. Clips knocked off instead of chipped.
2. Carelessness in striking arc on plate away from weld.
3. Careless chipping.



U. S. Navy Photo

FIGURE 55—Nicks and Notches Not in Weld—Fashion Plate on Sheer Strake—Z-ET1 Type Tanker.

ONE DOZEN STEPS TO INSURE SOUND WELDS

1. Make certain that edge preparation agrees with approved plan.

2. Do not begin weld if fit-up is too close or too wide.

3. If wide fit-up cannot be corrected, do not try to bridge gap or slug. Instead use backing strip or build up one edge as directed by the authorized inspector or official.

4. Clean and dry edges before welding.

5. Select the electrode called for by the approved plans and specifications. New two-color marking will aid identification.

6. Set machine in accordance with electrode, making allowance for cable length. Be sure of polarity. (Note settings recommended by electrode manufacturers.)

7. Make certain that electrode size will insure penetration in bottom of groove. Check with groove gauge.

8. Be sure electrodes are neither too dry nor too damp.

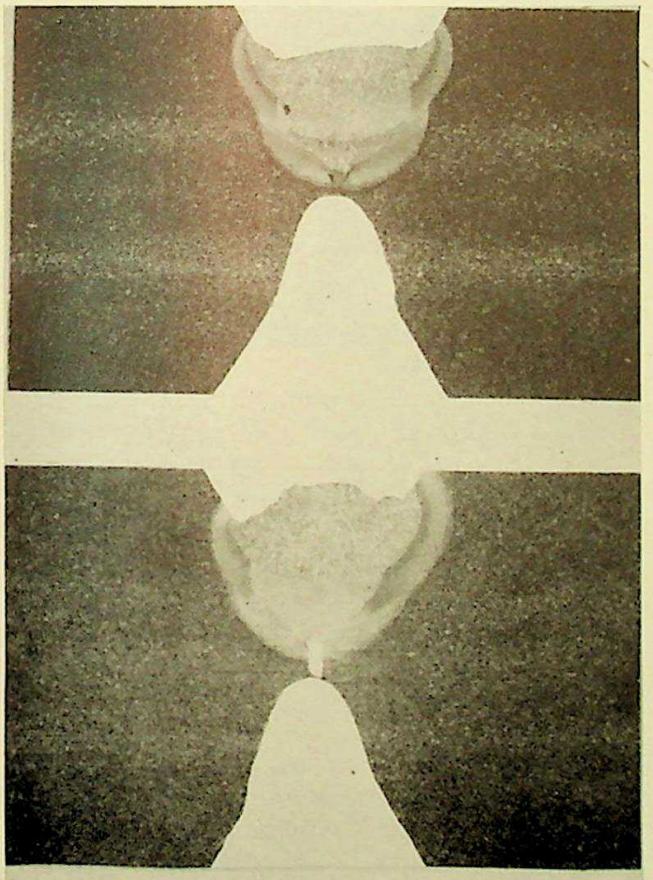
9. Complete each weld by filling in craters.

10. After each pass, clean beads carefully and look for cracks.

11. Before each pass, remove slag, porosity and cracks by chipping with proper round-nose chipping tool. Never bob or caulk cracked welds.

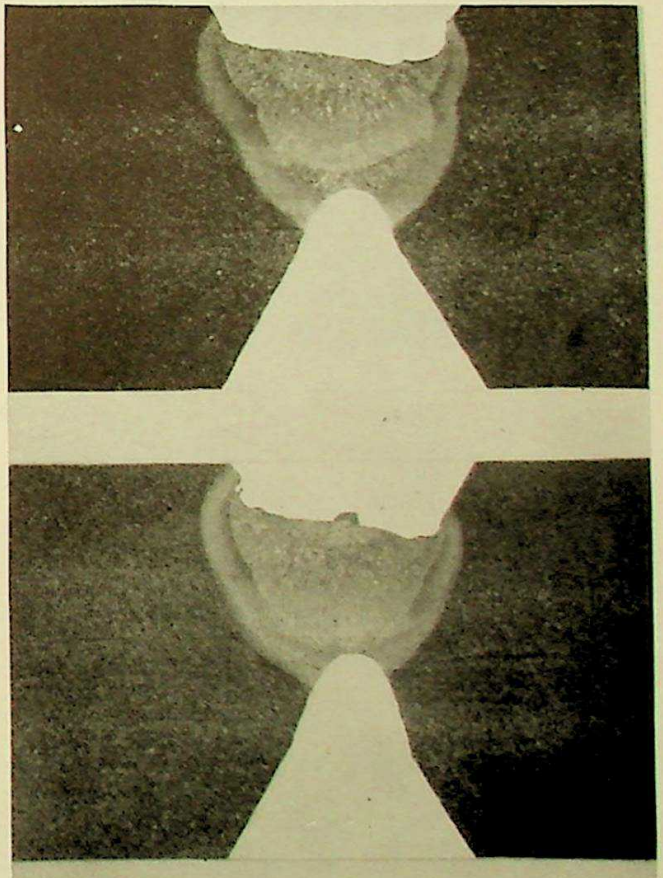
12. Use run-off tabs at ends of welds when using automatic welding. Carefully prepare and weld ends of grooves at intersections.

WRONG



UNACCEPTABLE CHIPPING OF ROOT

RIGHT

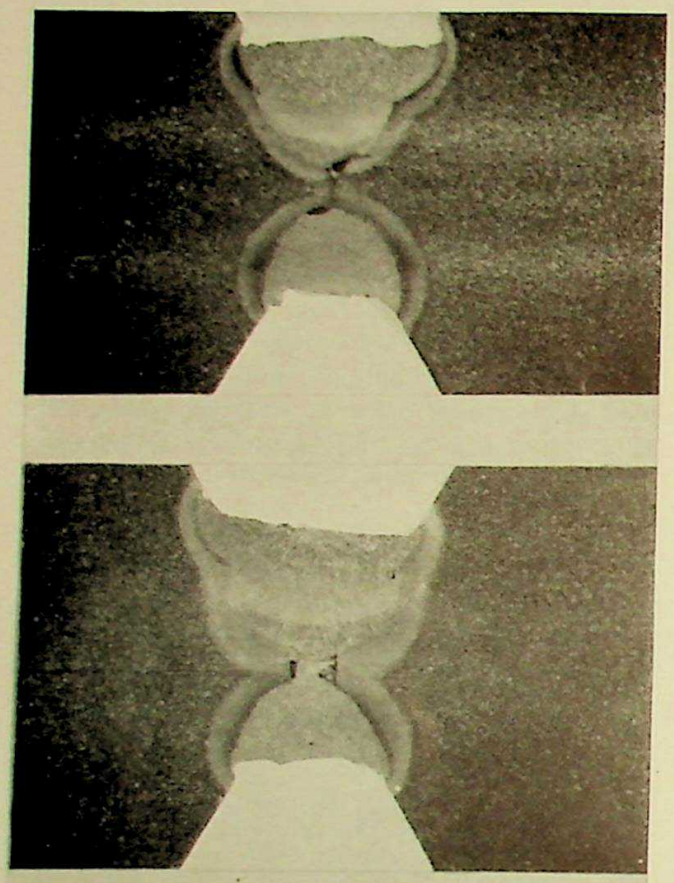


ACCEPTABLE CHIPPING OUT OF ROOT

U. S. Navy Photo

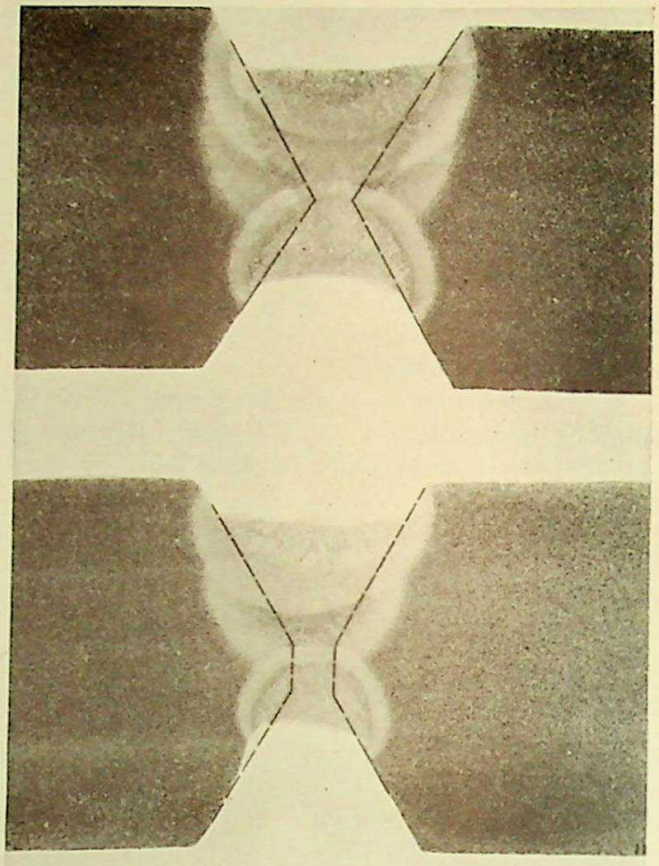
FIGURE 56.

WRONG



FLAWS AT ROOT OF WELD RESULTING FROM IMPROPER PENETRATION AND CHIPPING

RIGHT



SOUND WELDS AT ROOT RESULTING FROM PROPER PENETRATION AND CHIPPING

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FIGURE 57.

WRONG RIGHT

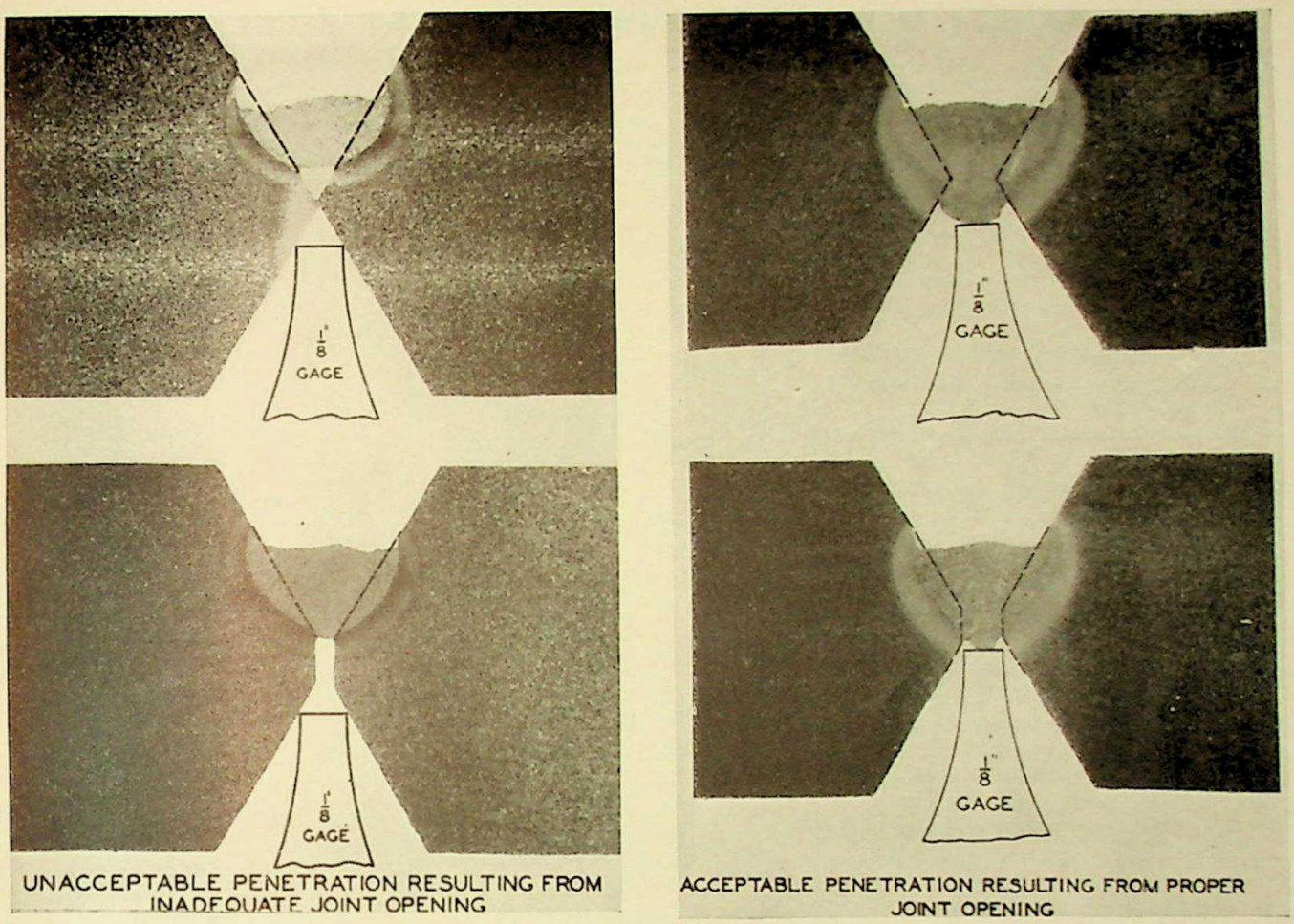

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FIGURE 58.

☆ ☆ ☆

In proportion to the number of vessels constructed, the number of structural failures has been small. The amount of defective welding, however, has been large. Fortunately the great majority of defects has not led to ship failure. It is plainly evident that if the percentage of defective welding can be reduced the number of structural failures can be materially reduced. Experience with pressure vessels proves that sound welding is both possible and practicable. If troops, passengers, crews and cargo are to be transported in complete safety, sound welding in the strength members of American vessels must be attained.

APPENDIX

FAULTY WELDING PRACTICES AND THEIR RESULTS

	Saddle welds	Cavities or poor penetration	Slag and dirt	Shrinkage cracks	Other nicks and cracks in weld metal	Buried cracks and cavities	Porosity	Nicks and notches not in weld
1. Fit-up—improper fit-up resulting in too wide or too narrow a welding groove	X	X	X	X	X		X	
2. Plate edge preparation—beveled edge too shallow, ragged edges, uneven weld groove, etc	X	X			X			
3. Electrode—use of wrong size or type	X	X		X	X		X	
4. Electrode—too dry or too damp			X				X	
5. Welding arc—too long or too short			X				X	
6. Machine setting—incorrect	X	X	X	X	X		X	
7. Speed—excess		X	X				X	
8. Sequence—failure to follow proper sequence				X	X			
9. Preheating—failure to preheat when required				X	X			
10. Chipping—improper chipping of weld groove at weld intersection	X	X	X		X			
11. Chipping—improper chipping, use of diamond-pointed tool	X	X	X		X			
12. Chipping—failure to back chip	X	X	X		X			
13. Chipping—careless chipping; knocking off clips instead of chipping them off								X
14. Craters—failure to chip craters out, or fill them in at end of welds				X				
15. Cleaning—failure to clean welding groove properly or to clean beads between passes		X	X				X	
16. Peening first pass					X			
17. Bobbing or caulking of weld defects to stop leaks—welding over cracked tacks						X		
18. Use of slugs		X						
19. Striking of arc—careless striking on plating								X

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